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投稿規定

1　資　格

原則として，気象庁職員に限る。ただし，気象庁職員との連名の場合は，この限りでない。

2　論文及び報文（以下「論文等」という。）の内容

未発表の原稿で，海洋（物理・化学・生物・地質など）及び海上気象（波浪・海氷・海気相互関係など）に関する論文並びに気象庁における海洋・海上気象業務の活動，そのために開発された測器及び方法に関する報文など。

3　書き方

(1) 用語は，欧文（原則として英文）とする。

(2) 論文等には，英文（300語以内）及び和文（800字以内）の要約を付ける。要約は，方法・測器・実験・観測の結果・仮定・理論などの中味が読みとれるように留意し，なるべく指定の長さで簡潔に書く。

(3) 論文等の始めには，題名・著者名及所属機関名を明記する。和文の要約にも同様のことを明記する。

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(7) 数式は，2行取りに書き，数式の文字及び記号をはっきりと説明する。

(8) 論文等の中に文献を引用する場合は，「ALLEN (1927)」又は「(ALLEN, 1927)」のように書く。

(9) 引用文献は，最後にまとめて付け，著者名のアルファベット順に並べる。書き方は次のようにする。

ALLEN, W.E. (1927): Surface catches of marine diatoms and dinoflagellates made by U.S.A. Pioneer in Alaskan waters in 1923. *Bull. Scripps Inst. Occanogr., Tech. Ser.* 1(4), 39–48.

BUDYKO, M. I. (1956): *The heat balance of the earth's surface.* Hydrometeorogical Publishing House, Leningrad, pp. 254.

VERONINS, G. and H. STOMMEL (1956): The action of a variable wind stress on a stratified ocean. *J. Mar. Res.*, 15(1), 43–75.

4　提出方法

投稿票を付け，本稿のほかにコピー（図及び表を含む。）2部を添える。

5　締切り

毎年気象庁公報により公示する。

6　送付先

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7　その他

論文等1編につき別刷り50部を著者に無料で送付する。

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Short-term temperature variation along 137°E in the subtropical region of the western North Pacific

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(Received November 13, 1980; Accepted February 16, 1981)

Abstract: Short-term variation of the characteristics of the Subtropical Countercurrent was studied based upon the ten temperature sections between 8°N and 25°N along the meridian around 137°E obtained on board research vessels of Japan and USSR from January 1979 through January 1980. The location of the thermal front, approximately corresponding to the Subtropical Countercurrent, in the upper ocean and the meridional gradient of temperature around the front showed the large variations. The thermal front shifted north in May and south in August. The meridional gradient of temperature was maximum in August. The southward displacement of the front in May and June partially cancelled the seasonal rising of sea surface temperature in the region between 20°N and 26°N. The whole eastward geostrophic flux across the section over the 500 db surface in July and August were almost twice times larger than those in January and March, while the westward flux was rather steady through the period.

1. Introduction

The Japan Meteorological Agency has continued the oceanographic survey along the meridian of 137°E on board the R/V Ryofu Maru in January and July. The principal view of the survey is to monitor the gross feature of the oceanographic conditions of the western North Pacific characterized with the parameters such as temperature, salinity, steric sea level and so on. Throughout the survey the fairly large year-to-year variations have been demonstrated not only in thermal structure but also in current system in the equatorial and subtropical region (MASUZAWA, 1967; NAGASAKA and SAWARA, 1972; MASUZAWA and NAGASAKA, 1975; NAGASAKA, 1979).

In this presentation rather short-term, as like as month-to-month, variations of the thermal structure and the current system in the region between 8°N and 25°N are studied on the basis of the ten meridional oceanographic sections along 137°E for a year. Particularly the study is focused on the variations of the Subtropical Countercurrent.

2. Data

In 1979 Japan and USSR frequently carried out the oceanographic survey along the meridian around 137°E. Namely, the Japan Meteorological Agency made two temperature sections from south of Japan to the equator on board the R/V Keifu Maru in May and June as part of the summer field experiment of the MONEX in addition to the routine survey on board the R/V Ryofu Maru. USSR also made several oceanographic sections from (25°N, 138°E) to near (9°N, 135°E). A part of the data telegraphed as BATHY/TESAC report was received at the Japan Meteorological Agency.

The cruises used in this study are shown in Table 1 and Fig. 1. The USSR's sections are strictly not meridional. But the deviation from the meridian of 137°E might be considered negligible for the zonality of oceanographic structure in this region (e.g., MASUZAWA, 1968; YOSHIDA, 1970). In this study all sections are treated to be arranged along 137°E.

On board the R/V Ryofu Maru and the R/V Keifu Maru stations were occupied at every 1° of latitude, while on board the USSR's vessel data were obtained every 6 hours and the interval of the station was uneven. Surveys other than the R/V Ryofu Maru were limited down to the depth of about 500 m.

Table 1. List of the oceanographic cruises.

Cruise	Date (North–South)	Vessel
79–01	Jan. 22 — 26	Ryofu Maru
79–03	Mar. 12 — 7	USSR's
79–05	May 4 — 7	Keifu Maru
79–06	June 15 — 13	Keifu Maru
79–07–1	July 17 — 14 (*)	Ryofu Maru
79–07–2	July 24 — 31	USSR's
79–08	Aug. 8 — 2	USSR's
79–11–1	Nov. 4 — 10	USSR's
79–11–2	Nov. 19 — 13	USSR's
80–01	Jan. 20 — 25	Ryofu Maru

(*) Stations 8°-13°N were occupied on July 1 and 2.

3. Results and discussions

(a) Temperature section

It is easily recognized from the temperature sections that the subsurface temperature

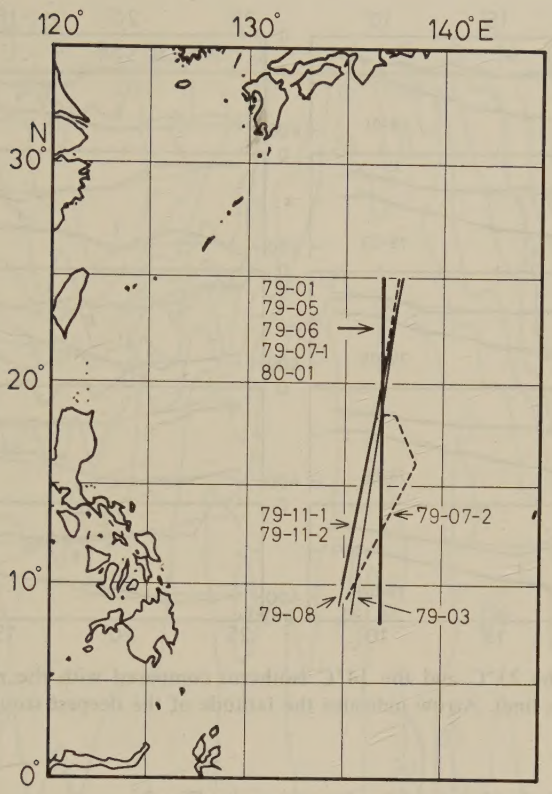

Fig. 1. Tracks of the oceanographic cruises.

in the northern half is high in winter and low in summer, and vice versa in the southern half. The largest annual ranges of temperature are observed at depth of 100 m in the northern and southern part, 200 m and 300 m in the middle part, and 400 m in the northern part. These phenomena are mainly caused by the changes in the depth of the main thermocline, which are partially accompanied with the north-south displacement of the current system in the region.

As already stated by MASUZAWA (1967), a temperature profile along 137°E shows that the depth of the main thermocline is the shallowest around 8°N, and in the vicinity of 15°N bifurcates into an upper portion and a lower portion. North of 15°N the depth of the upper thermocline becomes gradually shallow, while the lower one continues to deepen and has the maximum depth north of 30°N. Fig. 2 shows the depths of the 23°C and the 14°C isotherm in each section, which approximately correspond to the depths of the upper thermocline and the lower one, respectively. The

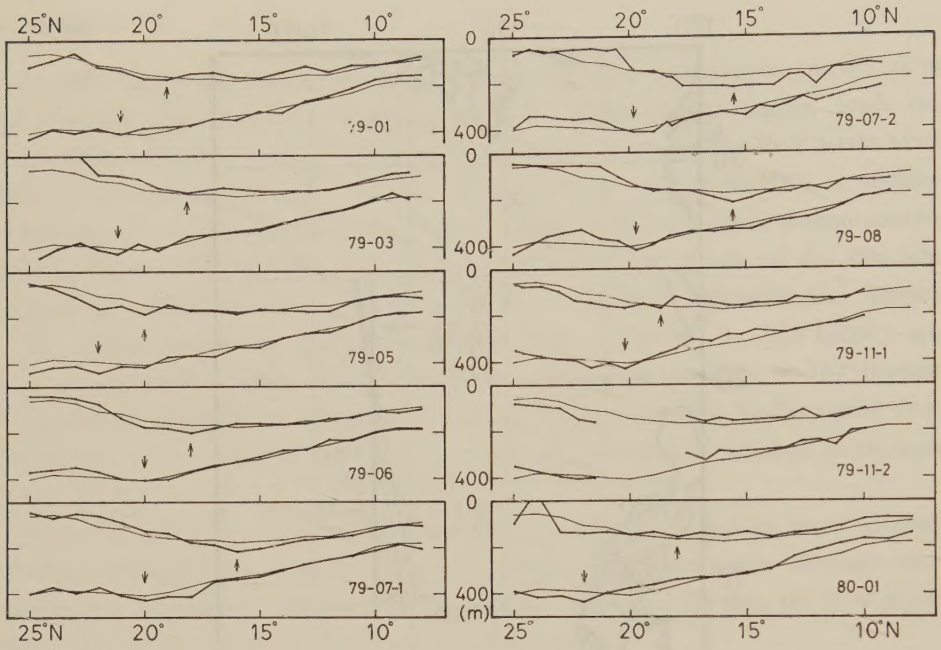

Fig. 2. Depths of the 23°C and the 14°C isotherm compared with the mean depths of the ten sections (thin line). Arrow indicates the latitude of the deepest trough for each profile.

mean depths of the isotherms are also given in Fig. 2.

The profile of the 23°C isotherm has some troughs. The deepest trough with an arrow in Fig. 2 is located north of 15°N. The region of the sharp rise of the depth of the 23°C isotherm north of the trough corresponds to the Subtropical Countercurrent. The depth of the trough is deeper in summer, and shallower in winter. Both trough and sharp rise, corresponding to the Subtropical Countercurrent, are situated at the highest latitude in cruise 79-05 and the lowest in cruise 79-07-2.

The profile of the 14°C isotherm also has the trough in the vicinity of 20°N, change in depth and location of which are restricted within narrower ranges than those of the 23°C isotherm. The trough does not clearly appear in cruises 79-01, 79-03 and 79-05. This means that the Subtropical Countercurrent is confined in a shallower layer.

(b) Sea surface temperature

The Subtropical Front associated with the Subtropical Countercurrent is usually recognized in the meridional profiles of sea surface temperature except in summer (WHITE et al., 1978). Fig. 3 shows the variation of the zonal mean of sea surface

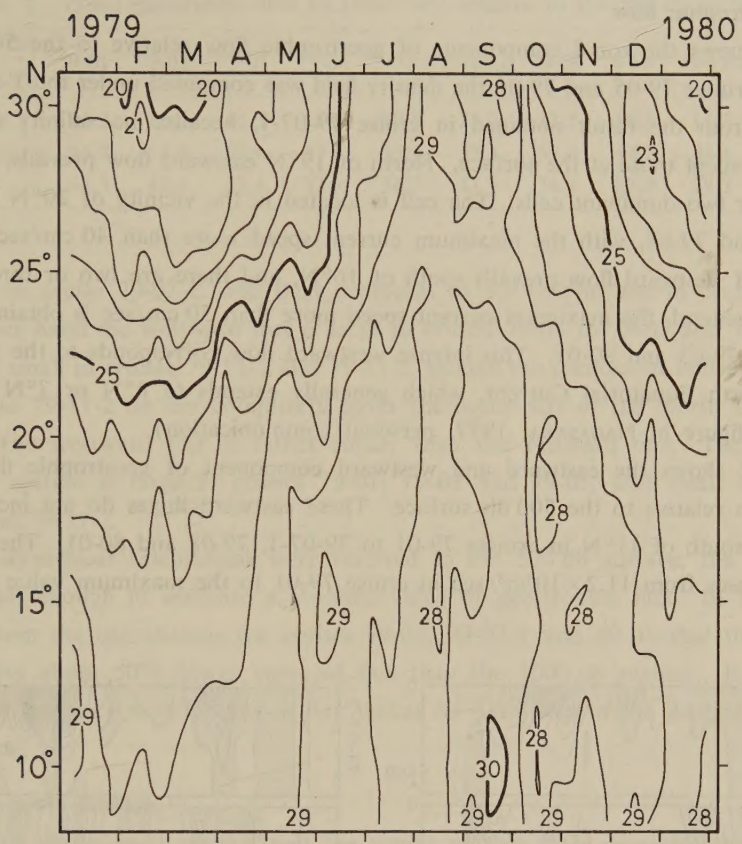

Fig. 3. Temporal variation of the ten-day mean sea surface temperature zonally averaged over 135°-140°E.

temperature estimated from THE TEN-DAY MARINE REPORT (JMA) in the region 135°-140°E. The sea surface temperature between 20°N and 26°N does not increase from the first ten-day of May through the first ten-day of June in spite of a warming season. This phenomenon has a close relationship to weather conditions to some extent, because in the latter half of May a stationary front exists all over the region. But the fact that both the 23°C and the 14°C isotherm are shallower in cruise 79-06 than in cruise 79-05 is seen in Fig. 2. Thus, it is possible to infer that the southward displacement of the Subtropical Countercurrent has partially cancelled the seasonal increase of sea surface temperature.

(c) Geostrophic flow

Fig. 4 shows the zonal components of geostrophic flow relative to the 500 db surface. In cruises 79-05 and 79-06 the density field was computed under the T-S diagram assumed from the result obtained in cruise 79-07-1, because no salinity data were obtained except those at the surface. North of 19°N eastward flow prevails, and there are one or two dominant cells. The cell is located in the vicinity of 20°N in cruises 79-07-2 and 79-08, with the maximum current speed more than 40 cm/sec. On the other hand westward flow prevails south of 16°N, and there are two or three intense cells. In general, the maximum current speed more than 50 cm/sec is obtained except in cruises 79-03 and 80-01. This intense westward flow corresponds to the main part of the North Equatorial Current, which generally extends to 8°N or 7°N (inferred from the figure in NAGASAKA, 1977, personal communication).

Table 2 shows the eastward and westward component of geostrophic flux across the section relative to the 500 db surface. These eastward fluxes do not include ones that exist south of 11°N in cruises 79-01 to 79-07-1, 79-08 and 80-01. The eastward flux increases from $11.2\times10^6 m^2$/sec in cruise 79-01 to the maximum value of $23.2\times$

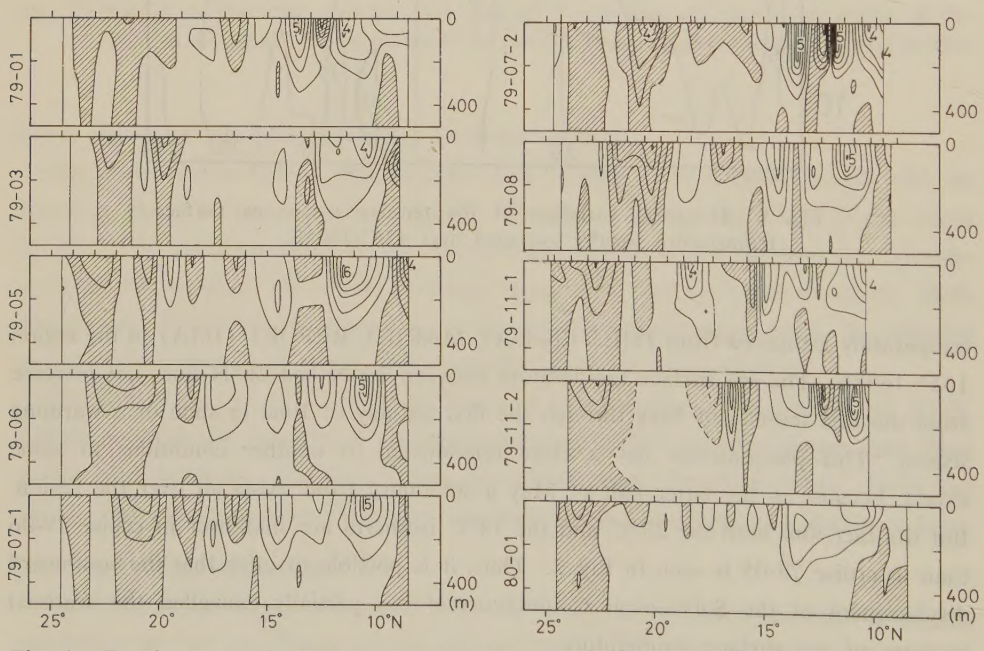

Fig. 4. Zonal geostrophic flow (cm/sec) relative to the 500 db surface. Areas of eastward flow are hatched. Numerals 4, 5 and 6 mean 40, 50 and 60 cm/sec respectively.

Table 2. Zonal geostrophic flux ($\times 10^6 m^3/sec$) relative to the 500 db surface.

Flux \ Cruise	79-01	79-03	79-05	79-06	79-07-1	79-07-2	79-08	79-11-1	79-11-2	80-01
Eastward	11.2	12.0	15.2	15.5	18.5	23.2	22.7	16.3	16.3	6.9
Westward	55.7	55.4	57.6	47.8	55.2	55.1	57.6	44.2	44.6	47.2
Net	44.5	43.4	42.4	32.3	36.7	31.9	34.9	27.9	28.3	40.3

$10^6 m^3/sec$ in cruise 79-07-2, and then decreases to $6.9 \times 10^6 m^3/sec$ in cruise 80-01. On the other hand the westward flux is large in cruises 79-01 to 79-05 and 79-07-1 to 79-08, and small in cruises 79-11-1 and 79-11-2, though the sections in cruises 79-07-2, 79-11-1 and 79-11-2 do not completely cover the main part of the North Equatorial Current. The westward flux is rather steady than the eastward one. The net flux across the section is large in cruises 79-01, 79-03 and 79-05, and small in cruises 79-11-1 and 79-11-2.

All the dynamical calculations were referred to the 500 db surface, the depth of which is not enough to estimate a absolute value of geostrophic flux. In fact, it is revealed from the calculations for cruises 79-01, 79-07-1 and 80-01 that the 500 db surface gives about 50% lower value of flux than the 1000 db surface. It is, however, found that such a difference in flux makes no difference in the general trend of the variation.

(d) Large scale feature

It remains uncertain to what extent the results of this study represent the changes of the meridional temperature profile in the western North Pacific. Fig. 5 shows the depth of the 23°C isotherm along several meridians in the subtropical region of the western North Pacific. In this figure the data obtained on board the R/V Shoyo Maru and the R/V Hakuho Maru are included (Research Division, Fisheries Agency of Japan, 1979; MIYATA et al., 1979). The sharp northward rise of the 23°C isotherm is located near 20°N at all the profiles except 155°E (Fig. 5 (b) broken line), and the change in the latitudinal location between Fig. 5(a) and (b) is not so large as the case between cruise 79-05 and 79-06. Moreover, on 180°E the difference of the gradient of isotherm among the three profiles is also small (Fig. 5 (c)). The meridional thermal gradient in the upper ocean along 139°40′E in November is found to be weaker than that along 140°30′E in May and also 137°E in November, on the basis of the temperature section obtained on board the R/V Shoyo Maru (Research Division, Fisheries Agency of Japan, 1980). It is found from Fig. 5 (a) and (b) that the profile along 155°E

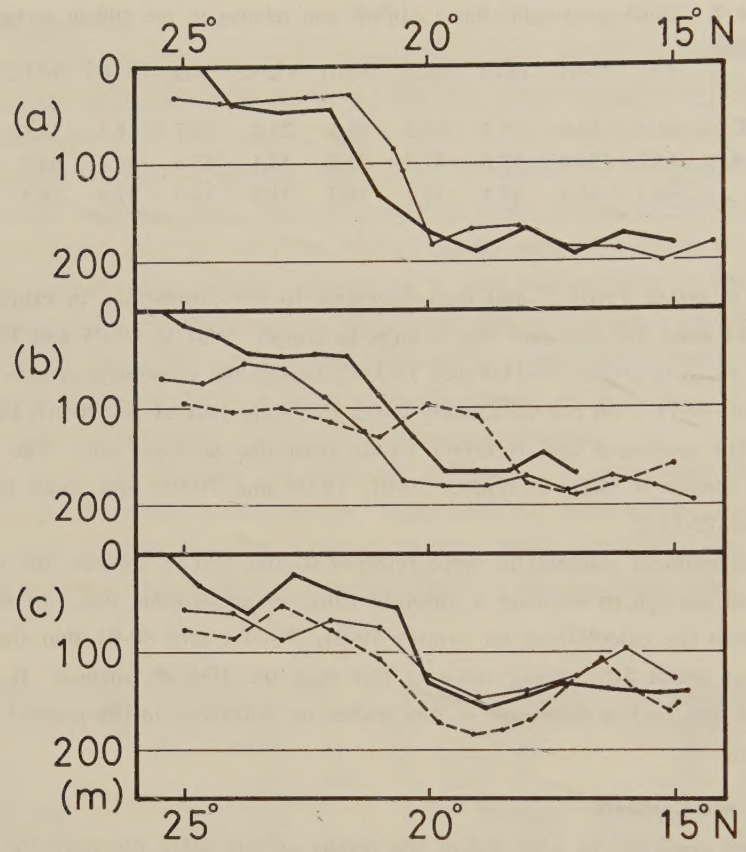

Fig. 5. Depth of the 23°C isotherm.
(a) 145°E, April 25-28, USSR's vessel (thick line); 140°30'E, May 4-7, USSR's vessel (thin line).
(b) 134°30'E, May 26-29, Shoyo Maru (thick line); 150°E, June 3-5, Hakuho Maru (thin line); 155°E, June 7-12, Ryofu Maru (broken line).
(c) 180°E, March 10-14 (thick line), June 18-22 (thin line), August 15-21 (broken line), USSR's vessel.

is not similar to those west of 150°E. This finding may suggest that the eastward extent of the subgyres in the western subtropical gyre, reported by HASUNUMA and YOSHIDA (1978), is confined to such a longitude.

Concluding remarks:

The Subtropical Countercurrent during January 1979–January 1980 is weak in

winter and strong in summer. It is located north in May and south in August. The results do not always agree with the long-term mean seasonal changes both in the strength and latitudinal location of the Subtropical Front derived by WHITE et al. (1978).

Acknowledgement

The author wishes to express deepest appreciation to Mr. Shunji KONAGA, Head of the Oceanographical Research Division, Meteorological Research Institute, for his kind advice throughout the preparation of the manuscript.

References

HASUNUMA, K., and K. YOSHIDA (1978): Splitting of the subtropical gyre in the western North Pacific. J. Oceanogr. Soc. Japan, **34**, 160-172.

MASUZAWA, J. (1967): An oceanographic section from Japan to New Guinea at 137°E in January 1967. Oceanogr. Mag., **19**, 95-118.

MASUZAWA, J. (1968): Second cruise for CSK, Ryofu Maru, January to March 1968. Oceanogr. Mag., **20**, 173-185.

MASUZAWA, J., and K. NAGASAKA (1975): The 137°E oceanographic section. J. Mar. Res., Supplement, **33**, 109-116.

NAGASAKA, K. (1979): The oceanographic section along 137°E. Proceedings of the Fourth CSK Symposium, Tokyo, 1979, 313-320.

NAGASAKA, K., and T. SAWARA (1972): A preliminary report of the cruise of the R/V Ryofu Maru in January-March 1971. Oceanogr. Mag., **24**, 25-38.

WHITE, W. B., K. HASUNUMA and H. SOLOMON (1978): Large-scale seasonal and secular variability of the Subtropical Front in the western North Pacific from 1954 to 1974. J. Geophys. Res., **83**, 4531-4544.

YOSHIDA, K. (1970): Subtropical Countercurrents: Band structures revealed from CSK data. In, The Kuroshio, East-West Center Press, Honolulu, 197-204.

Data

MIYATA, M., K. TAKEUCHI and K. KUTSUWADA (1979): Summary of the oceanographic observations. In, Preliminary report of the Hakuho Maru cruise KH-79-2 (MONEX Cruise), Ocean Research Institute, University of Tokyo, 76-80.

Research Division, Fisheries Agency of Japan (1979): Report on 1979 research cruise of the R/V Shoyo Maru (May-July). pp. 74.

Research Division, Fisheries Agency of Japan (1980): Report on 1979 research cruise of the R/V Shoyo Maru (October-December). pp. 57.

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北西太平洋亜熱帯海域の 137°E 線における水温の短期変動

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1979年1月から1980年1月にかけて，日本とソ連の観測船によって得られたほぼ 137° E 線に沿った 8° N 付近から 25° N までの10水温断面について，亜熱帯反流の変化に主眼を置いて調べた。

ほぼ亜熱帯反流に対応する表層水温フロントは，この期間位置においても強さにおいても顕著な変化を示した。フロントは5月に北偏し，8月に南偏した。水温傾度は8月に最も強かった。5～6月のフロントの南進は20～26° N の海域における海面水温の季節上昇を打ち消すよう作用した。500 db 面を基準にした断面内の東向き地衡流量は7・8月には1・3月の約2倍であった。他方，西向き流量は比較的安定していた。

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Relation between the geostrophic flux of the Kuroshio in the Eastern China Sea and its large-meanders in south of Japan

Masaro SAIKI
The Japan Meteorological Agency

(Received January 31, 1981; Revised January 29, 1982; Accepted February 2, 1982)

Abstract: A correlation of the volume transport of the Kuroshio in the Eastern China Sea with the durations of the large-meanders of the Kuroshio south of Japan was discussed. The 5.5- and 8-year periods were recognized in the year-to-year fluctuation of the volume transport by harmonic analysis of the time-series from 1955 through 1978, and the superposition of the harmonic variations in the two periods allowed to introduce a hypothesis which enable to assign the durations of the large-meanders after 1953. Some oceanographic and atmospheric variations in the periods of 5.5- and 8-year were demonstrated in correlation with the year-to-year fluctuation of the volume transport of the Kuroshio.

1. Introduction

As commonly known, it is one of the peculiarities of the Kuroshio that the current has two quasi-stationary paths both of which persist for several years in south of Japan. Namely, they are the straight path on the continental slope and the large-meandered path with a large cold eddy in its shore side off Enshunada. The path with large-meander was observed three times in the last three decades, that is, 1953-1955, 1959-1963, and 1975-1980.

The fluctuation of the volume transport of the Kuroshio has been intensively studied in relation to the large-meanders in the current by several authors. NITANI (1972) showed that the large-meanders off Enshunada in the past three decades were accompanied with large volume transport in the Eastern China Sea and small transport in southeast of Yakushima Island, respectively. Recently, KONAGA et al. (1980), introducing a simple model on the behavior of the warm and cold eddies which were stationary located in south of Japan, intended to explain the mechanism of the complicated fluctuations of the volume transport in the two waters.

In this article the author would like to study the two periodical variations in the year-to-year fluctuation of the volume transport of the Kuroshio in the Eastern China Sea in correlation with the large-meanders.

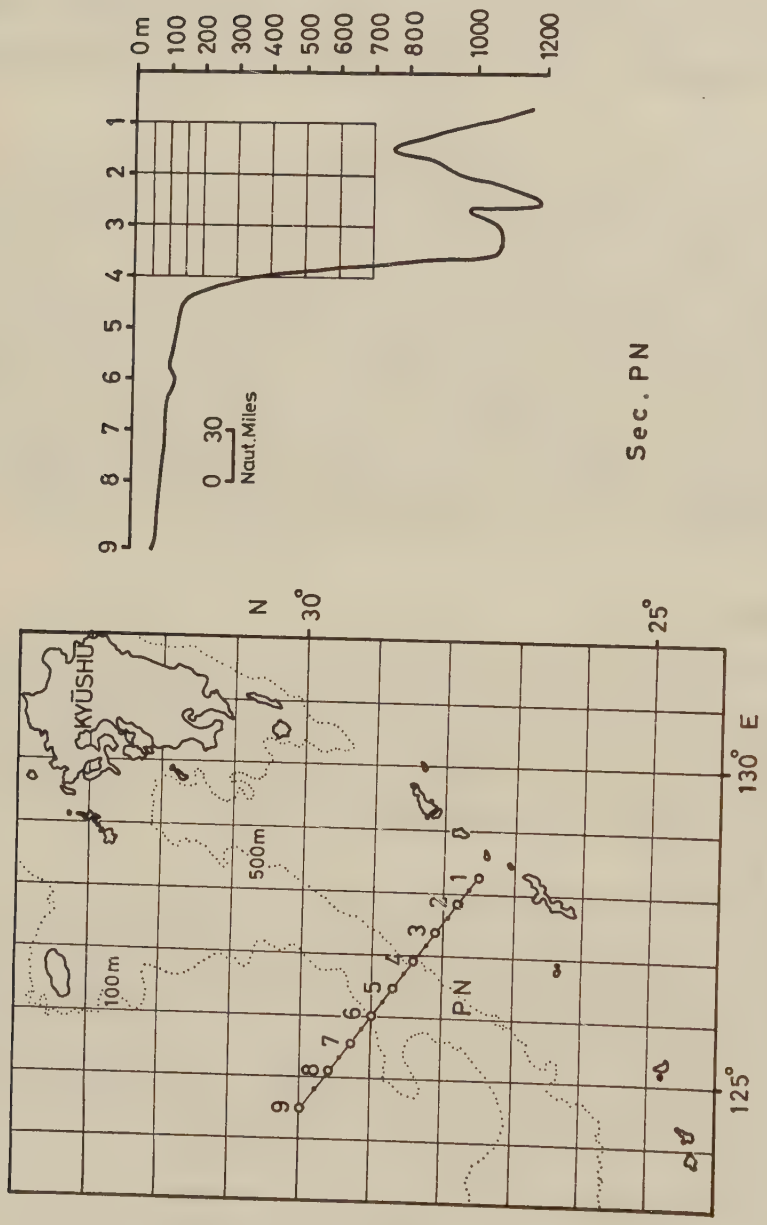

Fig. 1 Geographical location of the hydrographic section PN and bottom relief along the section. Lattice in right side indicates the area for geostrophic computation.

2. Volume transport of the Kuroshio in the Eastern China Sea

Since 1955 the Nagasaki Marine Observatory has carried out hydrographic surveys on board R/V Chofu Maru in the Eastern China Sea to obtain the general feature of the oceanographic conditions, in particular, seasonal and year-to-year variations of the Kuroshio. In the early periods they made semi-annual observations and since 1972 seasonal observations have been routinely conducted as a part of the marine pollution monitoring network of the Japan Meteorological Agency. Among the profiles made on board R/V Chofu Maru the section so-called PN-line northwest of Okinawa Island is the most adequate to monitor the volume transport of the Kuroshio in the Eastern China Sea. Nine hydrographic stations are occupied along the section, with every 30 miles except 40 miles between PN-8 and PN-9, as shown in Fig. 1.

In the Eastern China Sea the axis of the Kuroshio adheres to the upper portion of the continental slope and in the section the swift current is generally observed between PN-3 and PN-4. The volume transport of the geostrophic current over the 700 db surface in south of PN-4 is analysed in the present work. At PN-4 the water depth is shallower than the 700 db surface and about 300 meters. In order to estimate the fictitous geostrophic flux over the 700 db surface between PN-3 and PN-4, the temperature and salinity fields are assumed by extrapolating the isolines on the profiles disregarding the seabed around PN-4, and the total volume transport including the

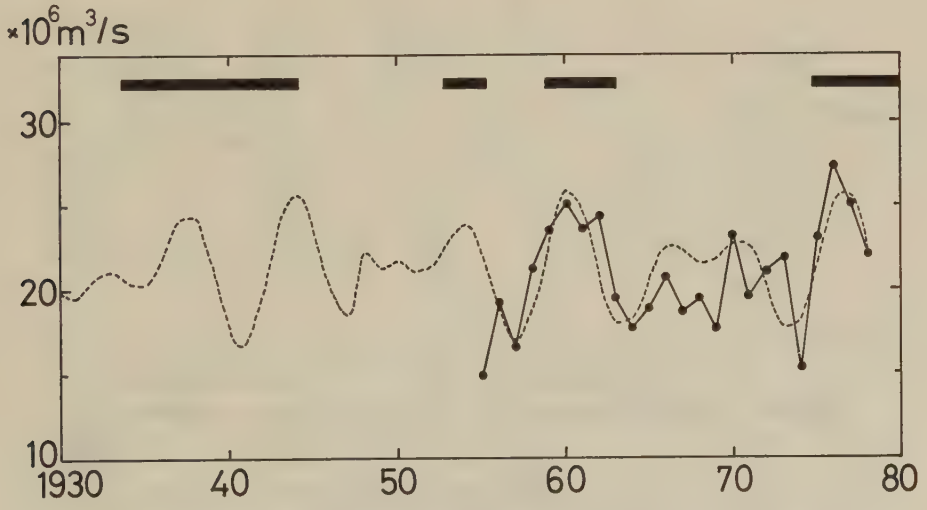

Fig. 2. Time-series of the annual mean volume transport of the Kuroshio in the Eastern China Sea (solid line), its extrapolated march (dotted line) and the periods occupied with the large-meander of the Kuroshio off Enshunada (bars).

fictitous water is examined. The volume transport was obtained for each 71 surveys from 1955 through 1978, the average of them is estimated to be $21.3\times10^6m^3/s$ with a standard deviation of $5.5\times10^6m^3/s$.

In Fig. 2 time-series of annual mean volume transport is shown in the solid line and the bars in the upper portion in the figure indicate the periods occupied with the large-meander of the Kuroshio off Enshunada. It is easily recognized from Fig. 2 that the large-meanders are accompanied with large volume transport in the Eastern China Sea as already stated by NITANI (1972). The mean of the volume transport is $23.1\times10^6m^3/s$ for the periods of the large-meanders and $20.3\times10^6m^3/s$ for the periods of the straight path.

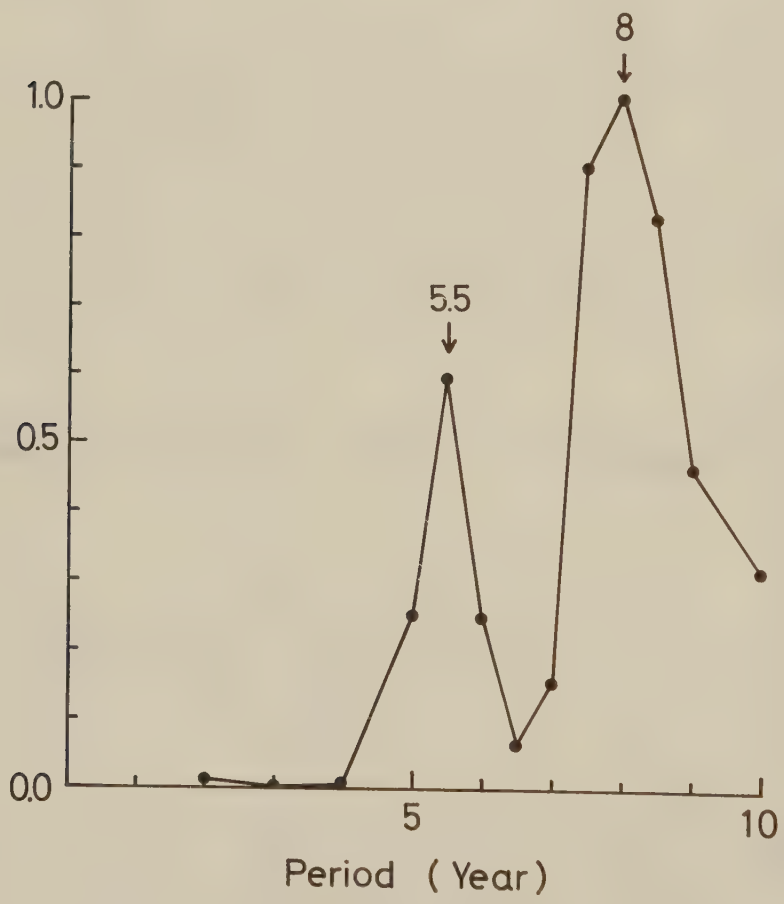

Fig. 3 Relative ratio of spectral densities for the fluctuation of the annual mean volume transport of the Kuroshio in the Eastern China Sea.

As indicated in Fig. 3, harmonic analysis of the march from 1955 through 1978 shows that 5.5- and 8-year variations are dominant in the year-to-year fluctuation of the volume transport. An extrapolation of the volume transport for the period prior to 1955 was attempted by the superposition of the two variations. The dotted line in Fig. 2 gives the extrapolated time-series of the volume transport before 1955. It is noteworthy that the correlation proposed by NITANI seems to be the case for the period prior to 1955 under such a simple extrapolation of the annual march of the volume transport.

3. Discussion

From the time-series of the variations of the volume transport in the periods of 5.5- and 8-year as given in Fig. 4, the author would like to introduce a correlation which differs from NITANI's conclusion between the large-meanders and the fluctuation of the flux of the Kuroshio in the Eastern China Sea. That is, the large-meanders seem to be formed when the variation of the volume transport in 5.5-year period trends

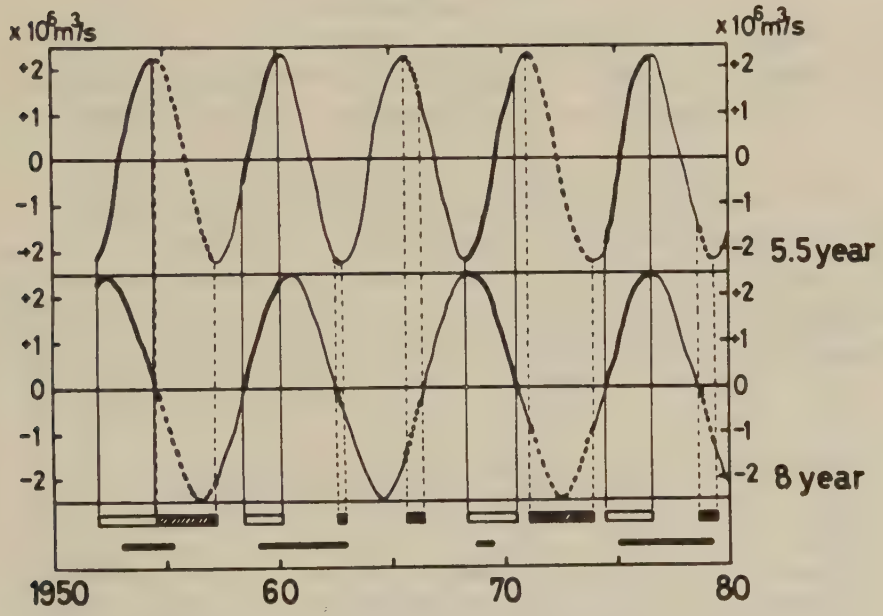

Fig. 4 Variations of 5.5- and 8-year periods in the volume transport of the Kuroshio and the durations of the large-meanders. Open and hatched bars show the possible periods for the formation and disappearance of the large-meander upon the author's hypothesis.

upward and the variation in 8-year period is larger than zero (positive). On the other hand, the shift back to the straight path seems to be observed when the former trends downward and the latter is negative. Upon this hypothesis the large-meander initiated in 1975 can be forecasted to disappear in 1980. The shift back of the meander path to the straight path was actually observed in the summer 1980.

The 5.5- and 8-year variations are not only limited in the fluctuation of the volume transport of the Kuroshio in the Eastern China Sea but also commonly observed in the various oceanographic and atmospheric phenomena in the Pacific Ocean. Fig. 5 shows the year-to-year fluctuations of the zonal wind speed at sea surface between

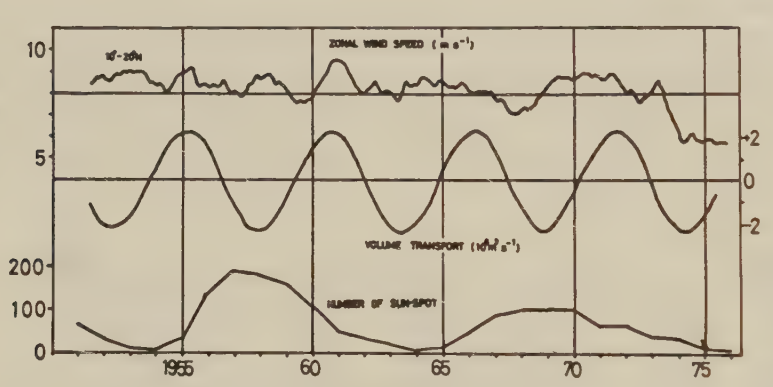

Fig. 5 Time-series of the zonal wind speed in the Pacific (10°-20°N, 130°E-140°W), the variation of 5.5-year period in the volume transport of the Kuroshio and sun spot numbers.

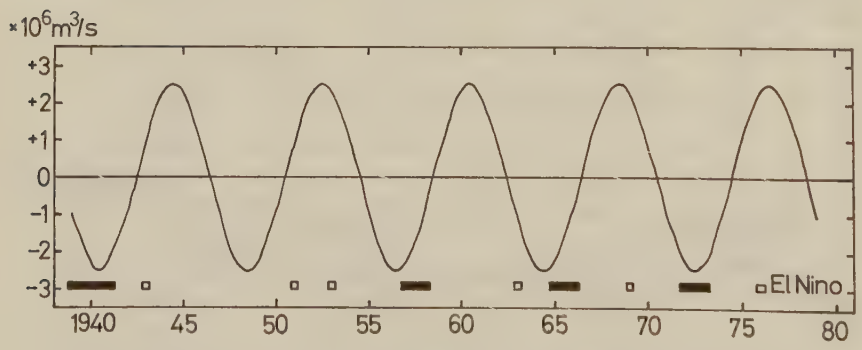

Fig. 6 The variations of 8-year period in the volume transport of the Kuroshio and the onset of El Nino events (solid bars: remarkable events, open bars: weak events).

10°N and 20°N (after MATSUKAWA, 1979), the sun spot numbers and the 5.5-year variation in the volume transport of the Kuroshio. The 5.5-year variation of the flux is in phase with the fluctuation of the zonal wind. Moreover, the maximum and minimum of the sun spot numbers are observed closely associated with the minimum of the 5.5-year variation of the flux. Fig. 6 shows the onset of El Niño events off Peru and the 8-year period variation of the volume transport of the Kuroshio in the Eastern China Sea. It might be notable that the large El Niño events indicated with solid bars in the figure occurred in the duration with negative values in the 8-year period variation, in other words, one of the conditions for the disappearance of the large-meander in the author's hypothesis.

Those correlations suggest that the variations in the period of 5.5- and 8-year in the volume transport of the Kuroshio in the Eastern China Sea are attributed to large-scale air-sea interaction over the Pacific Ocean. Further investigation on the whole system of the ocean and atmosphere in the Pacific Ocean is required for the better understanding of the large-meanders in the Kuroshio.

Acknowledgements

The author would like to express his gratitude to Mr. M. AMINO of the Japan Meteorological Agency for his valuable advice and to Professor Y. TOBA of Tohoku University for his encouragement throughout the study.

References

KONAGA, S., K. NISHIYAMA and H. ISHIZAKI (1980): Geostrophic transport in the Eastern China Sea and southeast of Yakushima Island—A case study. Oceanogr. Mag., **33**, 33-40.

MATSUKAWA, Y. (1979): A consideration on the Mechanism of Generation, Stagnation and Disappearance of the Kuroshio Meander. J. Oceanogr. Soc. Japan, **35**, 118-125.

NITANI, H. (1972): Beginning of the Kuroshio. In Kuroshio edited by H. Stommel and K. Yoshida, University of TokyoPress, Tokyo, pp. 129-163.

東シナ海の黒潮流量と黒潮大蛇行

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東シナ海における黒潮の地衡流量と黒潮大蛇行との関係について調査した。流量には5.5年と8年周期の変動が卓越しており，これら2つの周期の変動の組み合せによって，1953年以降の大蛇行の消

長を予測しうる仮説を提出した。また，海洋や大気における5.5年と8年周期の変動と黒潮流量の変動との関係についても論じた。

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NOTE

Preliminary evaluation of sea-surface temperature derived from IR observations of the GMS

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1. Introduction

The utilization of the satellite functions to obtain synoptic overview of oceans is an epoch-making event in the modern oceanography. In the various oceanographic measurements with spacecrafts, the sea-surface temperature derived with the IR (Infra-red) technique is a unique parameter available routinely for the time being. The IR images of sea-surface temperature enable to monitor the temporal changes in the global sea-surface temperature.

The quality of sea-surface temperature measurements from the space closely depends on the aerological conditions. The accuracy of the satellite estimates has been discussed from the theoretical and observational viewpoints by many authors. Recently, BARNETT et al. (1979) examined the discrepancies in sea-surface temperature between the GOSSTCOMP (Global Operational Sea Surface Temperature Computation) products derived from the IR data of the NOAA orbital spacecrafts and the direct measurements with AXBT along the two meridional sections in the central equatorial Pacific. They concluded that the satellite estimates were biased in comparison with the conventional measurements by 1°C to 4°C and the discrepancy field had a spatial structure which had not been intensively studied in the previous investigation.

In the present note the author would like to report some preliminary results of the evaluation of sea-surface temperature derived from the IR data of the GMS (Geostationary Meteorological Satellite "HIMAWARI").

2. Procedures

Since 1978 the images of the earth with the VISSR (Visible and Infra-red Spin Scan Radiometer) aboard the GMS at 140°E have been routinely taken every 3 hours as a part of the observations for the FGGE (First Global GARP Experiment). Although

the detailed description of the retrieval technique is out of the scope of the note (see, ABE and YAMAMOTO, 1979), the procedures to obtain sea-surface temperature in the Meteorological Satellite Center are briefly summarized in the followings.

The IR intensities are determined with sampling rate of 48μ radian and digitized for 8 bits. Among 3-hourly data those at 03, 09, 15 and 21 Z are processed for extraction of the daily sea-surface temperature representing one degree square of latitude and longitude in the waters from 50°N through 50°S and from 90°E through 170°W. The retrieval of each temperature is performed by an analysis of statistical histogram with 2500 to 6000 IR data accumulated from the four observations. The algorithm of the extraction is the same as the technique originally developed by SMITH

Fig. 1 An example of ten-day mean sea-surface temperature distribution.

et al. (1970) under the assumption that the warm wing of the histogram corresponding to sea-surface temperature follows the Gaussian distribution. The daily data which passed through the various quality control procedures are averaged over ten days.

The radiation of the IR channel (10.5-12.5 μm band) from the earth is slightly attenuated by atmospheric water vapor and the accuracy of sea-surface temperature highly depends on the correction for the attenuation. The GMS carrys no device to detect the moisture profile and the correction is obtained by using an empirical regression combined with the raw retrieved temperature, the climatological water vapor content and the nadir-angle. The magnitude of the correction is ranging from 5°C to 13°C, approximately.

Finally, ten-day mean sea-surface temperature distribution is depicted mainly by an objective method. The isothermochart contoured with 1°C intervals as shown in Fig. 1 is routinely disseminated by the meteorological radio facsimile from the JMA. The grid-point values of ten-day means are tabulated in the "Monthly Report of the Meteorological Satellite Center".

3. Evaluation

The evaluation of the GMS estimates of ten-day mean sea-surface temperature was performed for 36 products from July 1979 through June 1980. For the comparison with the GMS measurements, the conventional sea-surface temperature chart issued from the JMA as "The Ten-Day Marine Report" were digitized at the center of each grid of one degree latitude and longitude. The Report being prepared for the area in the western North Pacific, the present evaluation was conducted only in the northern half of the GMS coverage.

(1) Success rate of retrieval

As well known, the availability of sea-surface temperature with the IR technique is strictly restricted by existence of clouds. Fig. 2 shows the percentage of numbers of ten-day periods in which temperature was successfully extracted during the year. The success rate of the retrieval widely fluctuated from one area to another. In the waters between 10°N and 30°N the sea-surface temperature was most frequently derived. Particularly, in the area east of 140°E the success rate exceeded 90%. On the other hand, in the zone around 40°N the availability of the sea-surface temperature was extremely poor. In the east of Hokkaido the temperature was obtained only in few ten-day periods during the year. Those poor rates of retrieval were mainly due to persistent cloudiness.

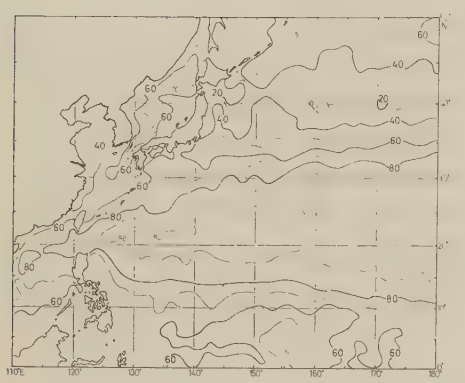

Fig. 2 Availability of ten-day mean sea-surface temperature from the IR data with the GMS; percentage of number of ten-day periods in which the sea-surface temperature was derived during the year (July 1979–June 1980).

Fig. 3 Annual average of the discrepancies in sea-surface temperature between the GMS products and the conventional products (°C). Positive sign means the former is higher than the latter in temperature.

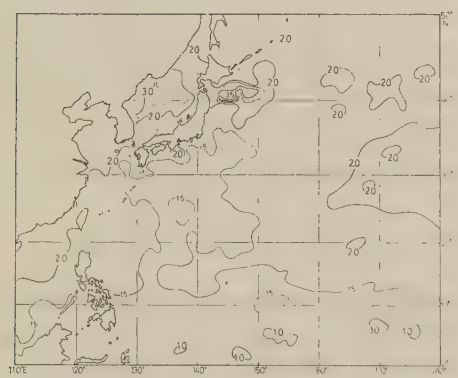

Fig. 4 Standard deviation associated with the annual average given in Fig. 3 (°C).

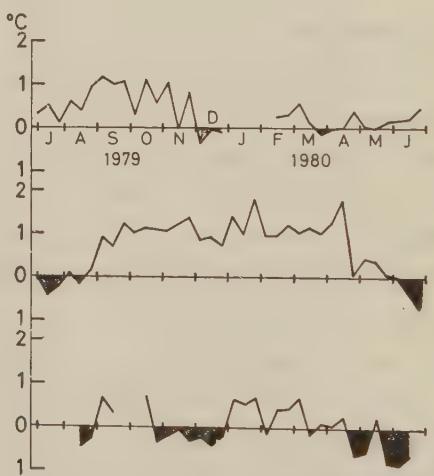

Fig. 5 The variations of the discrepancies averaged over 5 degree squares of latitude and longitude. Each square is centered at 37.5°N•147.5°E (upper), 27.5°E•162.5°E (middle) and 7.5°N•142.5°E. Shaded area shows that the satellite estimate is higher than the conventional data in temperature.

(2) Accuracy of temperature

The evaluation of the accuracy of the GMS estimates were made by comparison with the conventional data at each grid point. The annual average of the discrepancies and its standard deviation are shown in Fig. 3 and Fig. 4, respectively. The magnitude of the difference in temperature was scattered with considerably wide range from waters to waters. In general, the sea-surface temperature derived from the GMS observations was lower in the north of 10°N and higher in the equatorial regions, respectievly, compared with the direct measurements. The magnitude of the annual mean of the discrepancies was around 1°C with the exception of over 2°C in the seas adjacent to Japan. The standard deviation associated with the annual average of the discrepancies was ranged from 1°C in the equatorial area through over 3°C in the seas adjacent to Japan.

Those figures suggest that the accuracy of the GMS estimates is not so sufficient as to be applicable to the discussion required the absolute values of temperature such as interannual comparison. Fig. 5 shows the fluctuation of discrepancies averaged over 5 degrees square of latitude and longitude. Although it is difficult to discuss the characteristic of the fluctuations, it can be safely said that the magnitude of the discrepancies was almost constant for 7 months from September 1979 through March 1980 in the square centered at 27.5°N and 162.5°E.

4. Remarks

The present note is not intended to draw conclusions on the accuracy of the GMS products of sea-surface temperature. For the time being, the discrepancies in temperature more than 2°C over large waters and their spatial/temporal fluctuations seem to restrict the applications of the products. However, the role of the IR data offered with the GMS are still extremely effective for detecting the thermal fronts, current pattern, and cold/warm eddies by themselves or by combining with the conventional observations. Further efforts to improve the retrieval algorithm are urgent for the applications such as climatological studies and interannual comparisons.

References

Abe, K. and K. Yamamoto (1979): Determination of sea-surface temperature from the Geostationary Meteorological Satellite "Himawari" infrared radiation data. (in Japanese) Tenki, **26**, 493-507.

Barnett, T. J., W. C. Patzert, S. C. Webb and B. R. Bean (1979): Climatological usefulness of satellite determined sea-surface temperatures in the tropical Pacific. Bull. Ameri-

can Meteorological Society, **60**(3), 197-205.
Meteorological Satellite Center (1979, 1980): Monthly Report of the Meteorological Satellite Center. July, 1979–June 1980.
SMITH, W. L., P. K. RAO, R. KOFFLER and W. R. CURTIS (1970): The determination of sea surface temperature from satellite high resolution measurements. Mon. Wea. Rev., **98**, 604-611.

GMS 赤外データによる海面水温の評価（序）

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静止気象衛星「ひまわり」の赤外画像から抽出された旬平均放射海面水温のうち北西太平洋域を対象に若干の評価を試みた。

その結果年間旬（1979年7月～1980年6月）を通じて，緯経度1度ます目毎の海面水温の抽出成功率は，10～30°N 付近では 90% 前後と非常に高い。しかし 40°N 付近では，雲の影響が多く年間のうち数旬しか海面水温が得られない海域もかなりある。また船舶からの通報データをもとに作成されている旬平均海面水温（気象庁全国海況旬報）に比べて，GMS による海面水温は，平均的に 10°N 以北では，1～2°C 低く赤道域では 1°C 内外高い傾向がみられる。

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NOTE

Climatological maps of wind stress field over the North Pacific Ocean

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Marine Department, J.M.A. files weather reports from ships of opportunity since 1961. The reports contain ship positions, ship times and observed values of several meteorological elements such as wind, air and sea surface temperatures. In the present

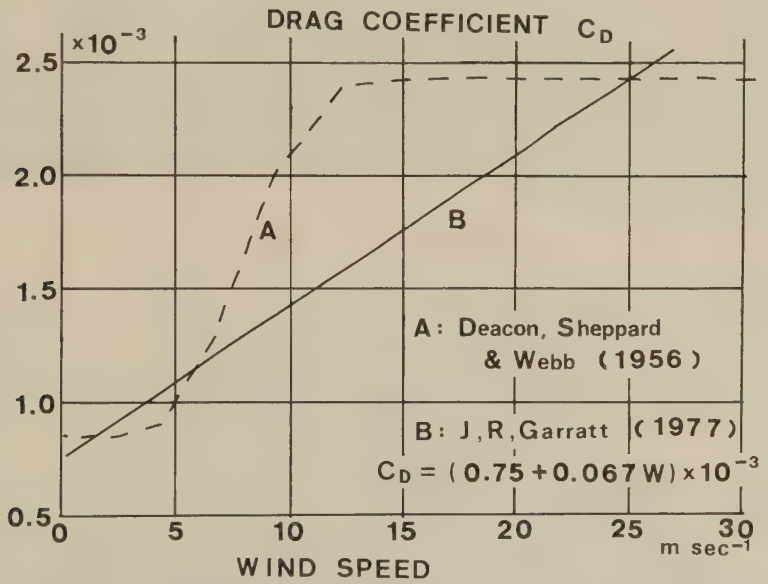


Fig. 1. The dependency of the drag coefficient in the bulk formula on wind speed. Broken curve (A) shows a dependency used in stress computation by HELLERMAN (1967) based on DEACON *et al.* (1956) and solid curve (B) that used in the present study based on GARRATT (1977).

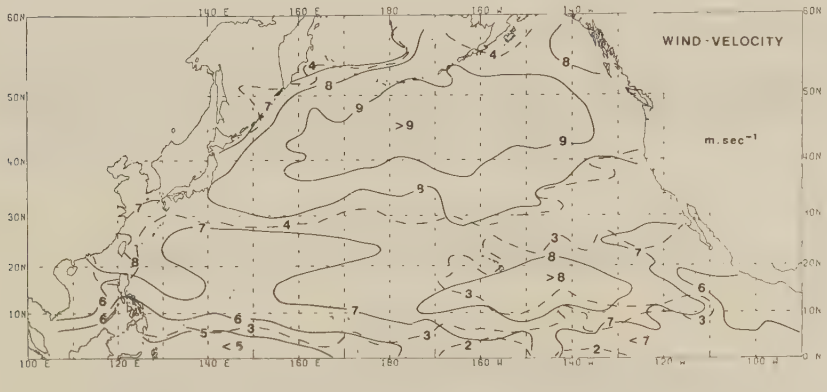


Fig. 2. Contours of averages of wind speed (solid lines) and of its standard deviations (broken lines). Units are $m\,s^{-1}$.

study, using ship reports during fifteen years of 1961-75, annual mean and monthly mean wind stress fields over the North Pacific are obtained. Stress averages every 2° between the equator and 60°N, every 5° between 100°E and 90°W were computed. Some reports were rejected, because wind velocity or wind direction was unavailable. Those whose wind speed exceeds 55 knots (about 28 m/s^{-1}) were also rejected because it is possible that they are faulse. In fifteen years of 1961-75, about five millions were used in our stress computation.

We considered each report as observed at nearly ten meters height and applied it to the following bulk formula,

$$\tau_x = \rho C_D V V x, \qquad \tau_y = \rho C_D V V y \tag{1}$$

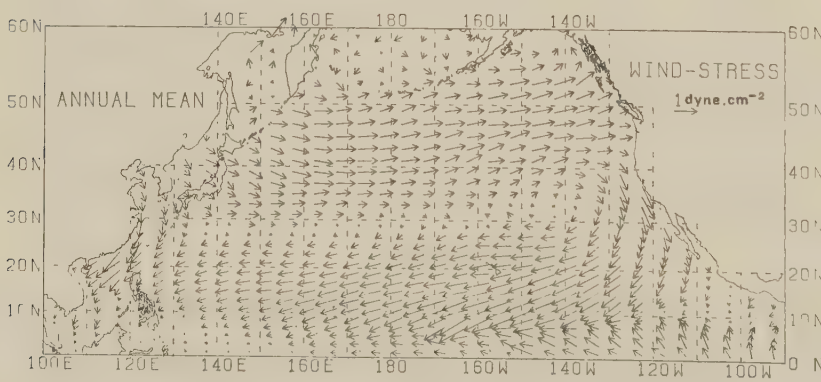


Fig. 3-1. Wind stress field for annual mean.

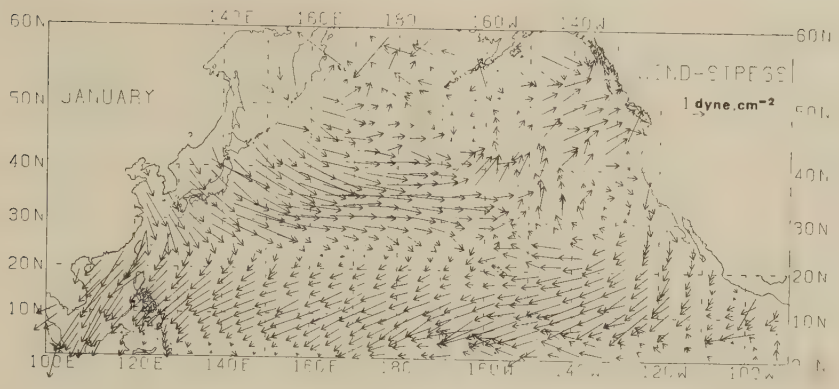


Fig. 3-2

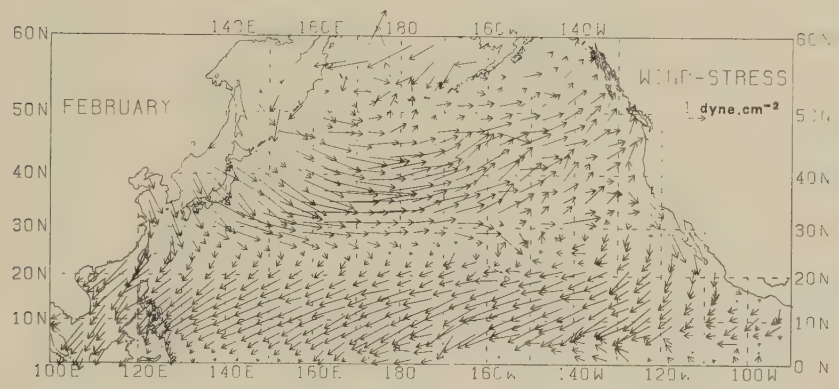


Fig. 3-3

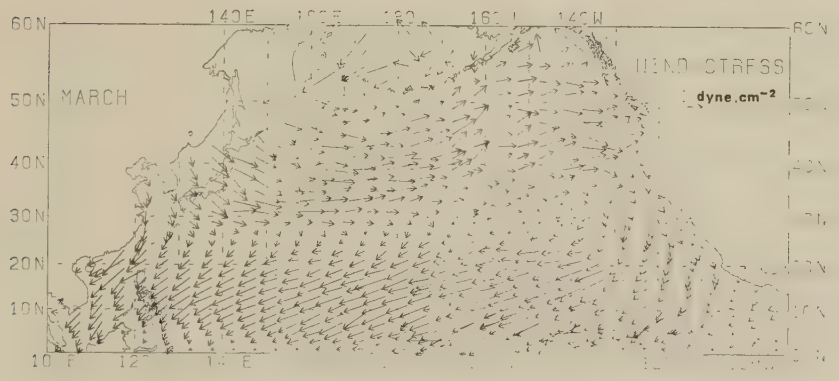


Fig. 3-4

Fig. 3-2 to 3-4. Wind stress fields for monthly mean.

Fig. 3-5

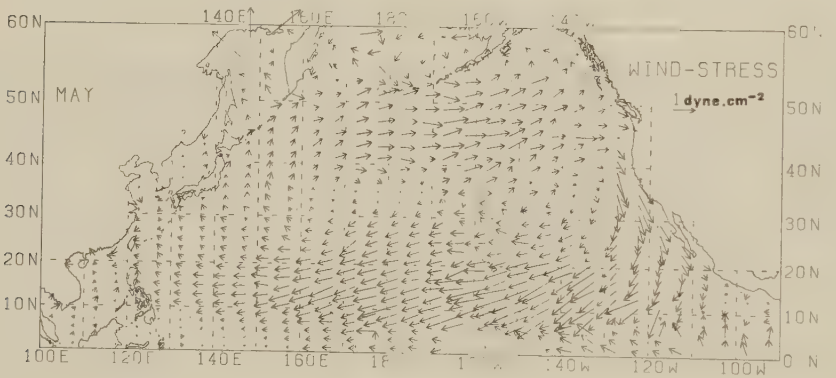


Fig. 3-6

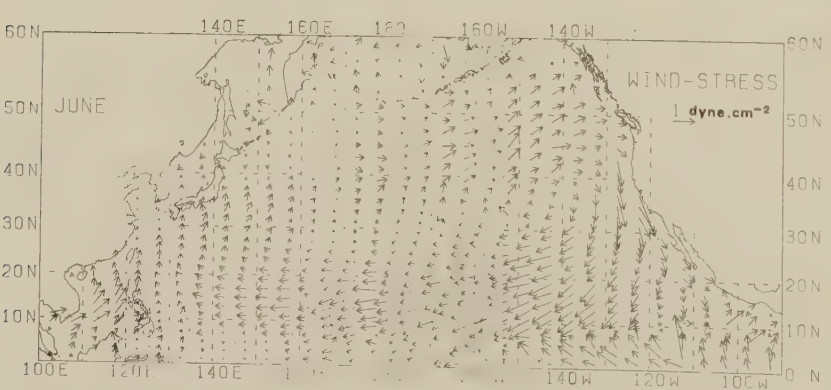


Fig. 3-7

Fig. 3-5 to 3-7. Wind stress fields for monthly mean.

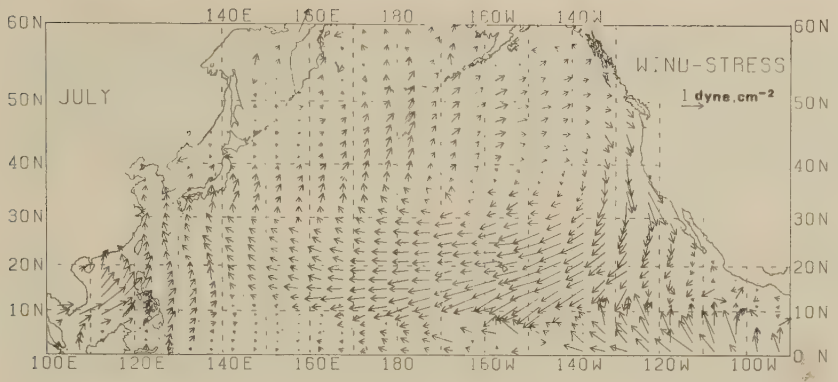


Fig. 3-8

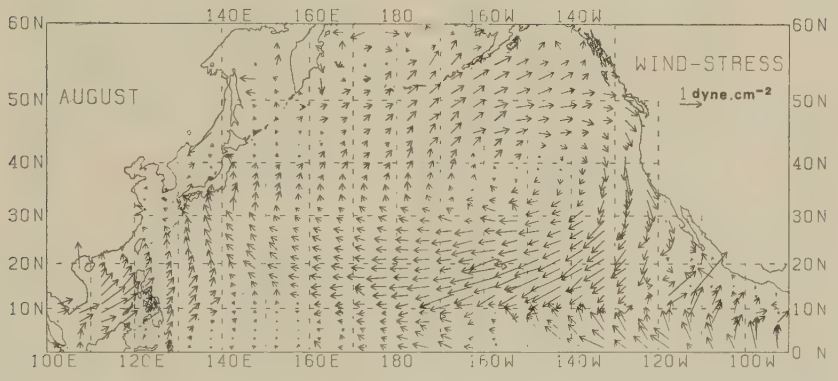


Fig. 3-9

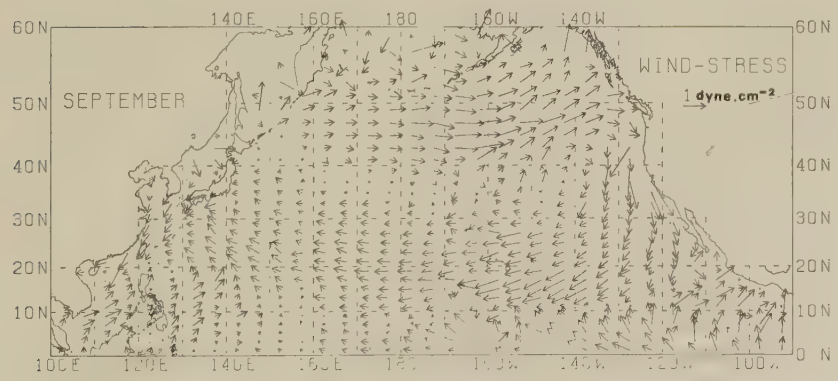


Fig. 3-10

Fig. 3-8 to 3-10. Wind stress fields for monthly mean.

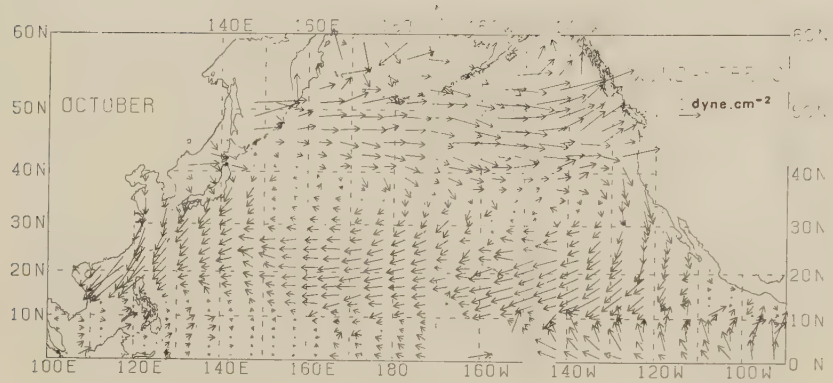


Fig. 3-11

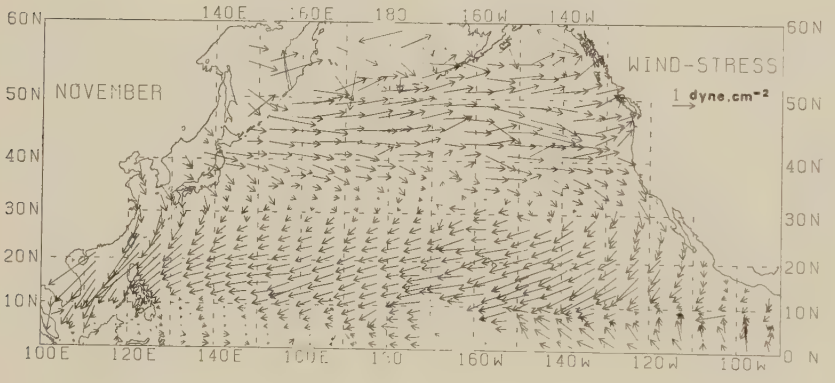


Fig. 3-12

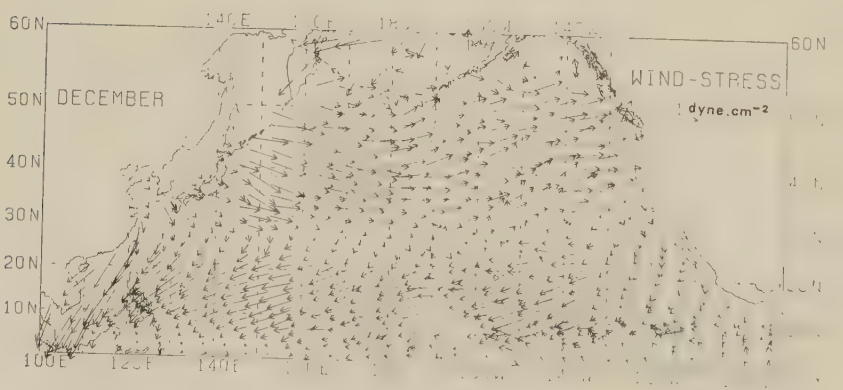


Fig. 3-13

Fig. 3-11 to 3-13. Wind stress fields for monthly mean.

Table 1. Air density given as zonal means for every 2° between the equator and 60°N in each month. Units are 10^{-3}g/cm^3.

**** AIR-DENSITY ****

LATITUDE	JAN,	FEB,	MAR,	APR,	MAY	JUN,	JUL,	AUG,	SEP,	OCT,	NOV,	DEC,
58-60N	1,29	1,30	1,30	1,29	1,27	1,26	1,25	1,24	1,25	1,27	1,26	1,29
56-58N	1,30	1,29	1,30	1,29	1,27	1,26	1,25	1,24	1,25	1,26	1,28	1,28
54-56N	1,28	1,28	1,28	1,29	1,27	1,26	1,25	1,24	1,24	1,25	1,27	1,26
52-54N	1,27	1,28	1,27	1,28	1,27	1,26	1,25	1,24	1,24	1,25	1,27	1,26
50-52N	1,28	1,27	1,27	1,28	1,27	1,26	1,25	1,24	1,24	1,25	1,27	1,27
48-50N	1,27	1,27	1,27	1,28	1,27	1,26	1,25	1,24	1,24	1,25	1,27	1,26
46-48N	1,27	1,27	1,27	1,28	1,27	1,26	1,25	1,23	1,24	1,25	1,26	1,26
44-46N	1,26	1,27	1,27	1,27	1,26	1,25	1,24	1,23	1,23	1,25	1,26	1,26
42-44N	1,26	1,26	1,26	1,27	1,25	1,24	1,23	1,22	1,22	1,24	1,25	1,25
40-42N	1,25	1,25	1,25	1,26	1,24	1,23	1,22	1,21	1,21	1,23	1,24	1,25
38-40N	1,24	1,25	1,25	1,25	1,24	1,22	1,21	1,20	1,20	1,22	1,23	1,24
36-38N	1,23	1,24	1,24	1,24	1,23	1,22	1,20	1,19	1,20	1,21	1,22	1,23
34-36N	1,23	1,23	1,23	1,23	1,22	1,21	1,20	1,19	1,19	1,20	1,22	1,22
32-34N	1,22	1,23	1,23	1,23	1,22	1,20	1,19	1,18	1,19	1,20	1,21	1,22
30-32N	1,22	1,22	1,22	1,22	1,21	1,20	1,19	1,18	1,18	1,19	1,20	1,21
28-30N	1,21	1,22	1,22	1,21	1,20	1,19	1,18	1,18	1,18	1,19	1,20	1,21
26-28N	1,21	1,21	1,21	1,21	1,20	1,19	1,18	1,18	1,18	1,18	1,19	1,20
24-26N	1,20	1,20	1,20	1,20	1,19	1,18	1,18	1,18	1,17	1,18	1,19	1,19
22-24N	1,19	1,20	1,20	1,19	1,19	1,18	1,18	1,17	1,17	1,18	1,18	1,19
20-22N	1,19	1,19	1,19	1,19	1,18	1,18	1,17	1,17	1,17	1,17	1,18	1,19
18-20N	1,18	1,19	1,19	1,18	1,18	1,17	1,17	1,17	1,17	1,17	1,18	1,18
16-18N	1,18	1,18	1,18	1,18	1,18	1,17	1,17	1,17	1,17	1,17	1,17	1,18
14-16N	1,18	1,18	1,18	1,18	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
12-14N	1,18	1,18	1,18	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
10-12N	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
8-10N	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
6- 8N	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
4- 6N	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
2- 4N	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17
0- 2N	1,17	1,16	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17	1,17

Table 2. The values of components of wind stress computed for quadrangles of 2-degree latitude by 5-degree longitude are indicated for annual mean and for monthly mean. Upper value in each quadrangle shows eastward component and lower one westward. United are 10^{-2}dyn/cm^2.

Table 2-1.

	100E	120E	140E	160E	180	160W	140W	120W	100W	
58-60N			43 65 6	-7 -30 -12 -25	-38 -10 14 21	-25 -32				58-60N
			125 84 47	10 -12 6 -24	-17 -21 -8 13	-8 30				
56-58N	COMPUTED WIND-STRESS		60 59 5 10	-25 -13 -19 7	24 -9 7 23	34 18 18 17	-28			56-58N
			-23 53 16 31	38 19 -8 4	-14 -23 -21 -1	-1 23 8 24	23			
54-56N	UPPER: EASTWARD COMPONENT		13 -7 8 0	5 -7 -21 13	19 36 11 55	50 55 44 34	15			54-56N
	LOWER: NORTHWARD COMPONENT		13 40 30 26	5 -27 -26 -17	-4 -23 12 -9	-4 7 21 27	41			
52-54N			207 -16 5 -5	25 32 17 13	31 41 41 64	72 83 82 85	80			52-54N
50-52N	ANNUAL MEAN		-71 -15 10 3	-13 -33 9 -2	0 12 4 6	14 20 23 21	61			50-52N
			43 10 8 47	51 30 44 53	48 61 67 69	83 89 92 84	76 56			
			-41 -11 4 10	-11 5 19 19	23 23 9 14	17 19 29 36	30 21			
48-50N			-3 29 49 19	80 66 60 58	62 57 73 74	78 89 87 100	80 64 36			48-50N
			6 16 -12 -19	-1 10 16 20	27 22 11 7	11 16 19 22	30 28 20			
46-48N		82	11 29 13 66	81 74 74 77	69 87 84 82	85 88 102 99	88 71 49			46-48N
		91	21 24 -4 -15	-1 7 14 20	20 9 8 18	5 8 17 14	30 16 12			
44-46N		-3	53 50 62 74	83 80 87 84	83 77 76 78	93 89 91 85	87 76 58			44-46N
		-26	-3 -31 -17 -18	-6 2 8 15	19 17 24 9	22 27 24 14	13 19 14			
42-44N	34 41	40 41 54 71	78 87 88 78	76 74 86 77	66 72 79 70	63 68 44				42-44N
	-53 -28	-2 -21 -23 -17	-7 0 7 11	15 17 19 21	26 26 22 7	4 3 -16				
40-42N	-16 28 59	47 48 56 73	83 83 87 79	79 69 64 70	68 71 59 66	65 53 34				40-42N
	-43 -46 -29	-20 -18 -20 -19	-14 0 2 17	11 17 11 25	14 18 26 21	6 -2 -34				
38-40N	9 9 34 23 45	48 57 67 81	85 86 81 79	75 66 60 50	31 61 54 48	46 43 31				38-40N
	-20 -26 -13 -19 -29	-19 -30 -29 -18	-11 -5 3 10	10 12 -5 25	29 23 13 19	-1 -30 -60				
36-38N	90 14 39 27 46	24 50 64 77	87 83 73 69	60 53 46 57	45 42 34 42	31 37 34 47				36-38N
	5 -32 -33 -24 -21	-33 -31 -12 -4	-3 0 1 12	10 7 10 3	26 27 21 6	-6 -28 -74 -82				
34-36N	18 11 18 36	34 47 57 62	64 63 63 58	49 44 37 37	36 34 24 21	22 26 27 31				34-36N
	-42 -41 -21 -28	-14 -17 -1 4	10 7 5 8	7 7 7 -6	-3 14 19 13	-3 -24 -57 -85				
32-34N	3 9 4 19	56 56 60 56	56 49 39 38	35 26 32 29	11 1 4 -1	-3 4 17 38				32-34N
	-37 -55 -31 -30	-3 -1 4 7	9 11 3 3	1 0 4 3	0 1 12 4	-10 -32 -52 -79				
30-32N	-2 12 15 26	39 43 40 41	33 30 24 15	11 13 19 -1	-15 -12 -10 3	-15 -13 0 18				30-32N
	-49 -55 -23 -9	1 -2 1 2	5 4 -1 -3	-7 -11 -12 -1	0 2 11 -2	-17 -34 -48 -67				
28-30N	-12 -3 6 10	10 22 17 20	11 6 2 2	-8 -10 -16 -4	-4 -29 -30 -36	-38 -35 -18 8	28			28-30N
	-67 -56 -19 0	-3 -3 0 3	0 -3 -5 -9	-11 -15 -16 -18	-7 -16 -8 -9	-23 -39 -49 -57	-52			
26-28N	-40 -20 -6 -7	-10 -8 -7 -13	-9 -14 -14 -22	-26 -27 -43 -45	-39 -45 -57 -55	-49 -45 -29 -10	9			26-28N
	-73 -43 -16 -2	-9 -8 -5 -5	-7 -9 -10 -16	-19 -17 -18 -13	-14 -15 -20 -10	-25 -34 -44 -49	-54			
24-26N	-113 -67 -33 -21 -23	-26 -25 -27 -31	-32 -32 -34 -37	-40 -47 -44 -75	-58 -74 -65 -69	-57 -54 -39 -22	-3 9			24-26N
	-232 -96 -30 -15 -8	-10 -6 -5 -6	-9 -10 -15 -14	-19 -18 -18 -27	-8 -10 -15 -20	-22 -39 -40 -39	-59 -41			
22-24N	-78 -48 -41 -36 -34	-39 -37 -42 -44	-46 -30 -30 -54	-52 -56 -64 -78	-85 -88 -95 -74	-63 -66 -50 -33	-19 5			22-24N
	-96 -51 -26 -17 -10	-11 -2 4 -7	-3 -10 -11 -18	-19 -21 -17 -20	-16 -12 -18 -27	-28 -38 -43 -45	-44 -37			
20-22N	-58 -67 -110 -67 -46 -43 -41	-49 -49 -55 -57	-56 -62 -71 -69	-74 -72 -77 -66	-93 -86 -100 -104	-87 -72 -58 -47	-35 -12 -12			20-22N
	-35 -37 -75 -49 -28 -19 -13	-12 -2 -2 -8	-8 -13 -19 -18	-20 -19 -21 -19	-18 -15 -22 -33	-41 -43 -60 -48	-39 -29 -16			
18-20N	-19 -56 -94 -83 -46 -48 -52	-54 -60 -66 -69	-74 -77 -81 -81	-80 -69 -78 -70	-96 -102 -117 -115	-103 -91 -85 -44	-19 -16 -10 -23			18-20N
	9 -36 -79 -49 -29 -18 -16	-10 -5 -10 -12	-14 -16 -20 -22	-22 -19 -16 -17	-12 -28 -38 -46	-51 -54 -53 -53	-49 -29 -15 0			
16-18N	-72 -45 -45 -24 -47 -30 -53	-59 -65 -66 -76	-78 -75 -84 -92	-90 -90 -104 -102	-117 -111 -116 -113	-108 -96 -76 -51	-33 -19 -12 -9			16-18N
	-65 -33 -53 -25 -28 -17 -10	-14 -10 -7 -11	-13 -17 -20 -18	-25 -18 -16 -18	-28 -34 -39 -47	-56 -59 -53 -56	-47 -34 -11 -3			
14-16N	20 -27 -22 -22 -42 -47 -30	-59 -66 -68 -71	-79 -87 -83 -97	-87 -94 -107 -114	-124 -105 -116 -120	-113 -104 -86 -64	-34 -26 -9 4	-19		14-16N
	-63 -34 -31 -9 -24 -18 -8	-13 -10 -6 -12	-19 -26 -28 -25	-17 -21 -31 -22	-30 -28 -40 -46	-55 -61 -65 -54	-45 -34 -22 -4	-26		
12-14N	18 1 -13 -4 -14 -32 -37 -44	-53 -60 -62 -76	-94 -99 -87 -92	-89 -97 -129 -114	-126 -117 -124 -116	-100 -86 -78 -47	-22 -11 -2 -9	-17 -4		12-14N
	9 -39 -27 -13 -7 -21 -17 -12	-14 -9 -12 -20	-25 -26 -22 -22	-26 -28 -38 -43	-37 -42 -46 -46	-49 -46 -62 -38	-23 -7 -12 3	-14 -16		
10-12N	11 -12 -1 -14 -14 -23 -26 -34	-47 -51 -55 -64	-72 -72 -80 -84	-88 -89 -108 -123	-114 -113 -104 -79	-78 -82 -68 -50	3 -18 -3 -1	-16 -22		10-12N
	-7 -63 -32 -15 -19 -17 -9 -11	-13 -10 -13 -19	-25 -24 -21 -25	-32 -32 -38 -38	-36 -38 -44 -30	-37 -42 -65 -25	3 -10 8 13	-13 -9		
8-10N	1 -10 -2 -6 -8 -12 -9 -26	-29 -42 -45 -57	-59 -57 -63 -73	-81 -74 -80 -126	-114 -101 -103 -90	-73 -64 -64 -32	-21 -36 -6 2	-10 -22		8-10N
	-18 -42 -44 -8 -11 -11 -3 -12	-10 -10 -13 -16	-24 -21 -26 -26	-37 -30 -38 -76	-56 -39 -32 -79	-38 -20 -15 -2	19 10 18 8	-4 -13		
6- 8N	1 -9 -14 -13 -3 3 -3 -20	-18 -30 -34 -48	-30 -56 -59 -44	-59 -69 -97 -128	-80 -83 -88 -68	-62 -45 -44 -38	-12 -8 -16 -3	13 19		6- 8N
	9 -26 -24 -10 -7 -2 -2 -11	-6 -8 -10 -13	-16 -17 -18 -24	-19 -16 -39 -69	-21 -6 -18 -2	-1 16 12 28	40 39 31 22	22 21		
4- 6N	5 -8 -7 -1 -1 5 -1 -2	-11 -18 -22 -29	-38 -31 -45 -60	-57 -52 -59 -78	-66 -70 -75 -66	-63 -38 -41 -43	-33 -26 -21 -4	0 10		4- 6N
	10 -12 -17 4 -2 -3 -2 -7	-5 -6 -5 -12	-8 -3 -8 -13	-4 -2 7 -16	7 14 23 21	30 37 33 48	60 78 56 53	56 71		
2- 4N	-1 -6 -9 0 -1 5 9 4	1 -9 -11 -18	-24 -28 -37 -37	-48 -55 -82 -38	-51 -47 -60 -75	-57 -62 -53 -41	-35 -29 -28 -24	-7 -1		2- 4N
	-1 -7 -24 2 -3 3 0 -5	-4 -2 -1 -4	-3 -3 1 2	6 6 18 7	8 23 9 36	35 40 41 41	47 63 73 63	66 49		
0- 2N	-7 0 1 3 6 10 6	7 -4 -5 -5	-19 -25 -29 -40	-47 -45 -53 -32	-40 -18 -103 -48	-63 -68 -56 -42	-53 -37 -24 -29	-14 -10		0- 2N
	-10 -6 2 3 4 1 -2	-1 0 1 1	2 -1 -1 4	2 6 7 12	13 7 38 17	24 24 28 26	37 42 41 47	73 64		
	100E	120E	140E	160E	180	160W	140W	120W	100W	

Table 2-2.

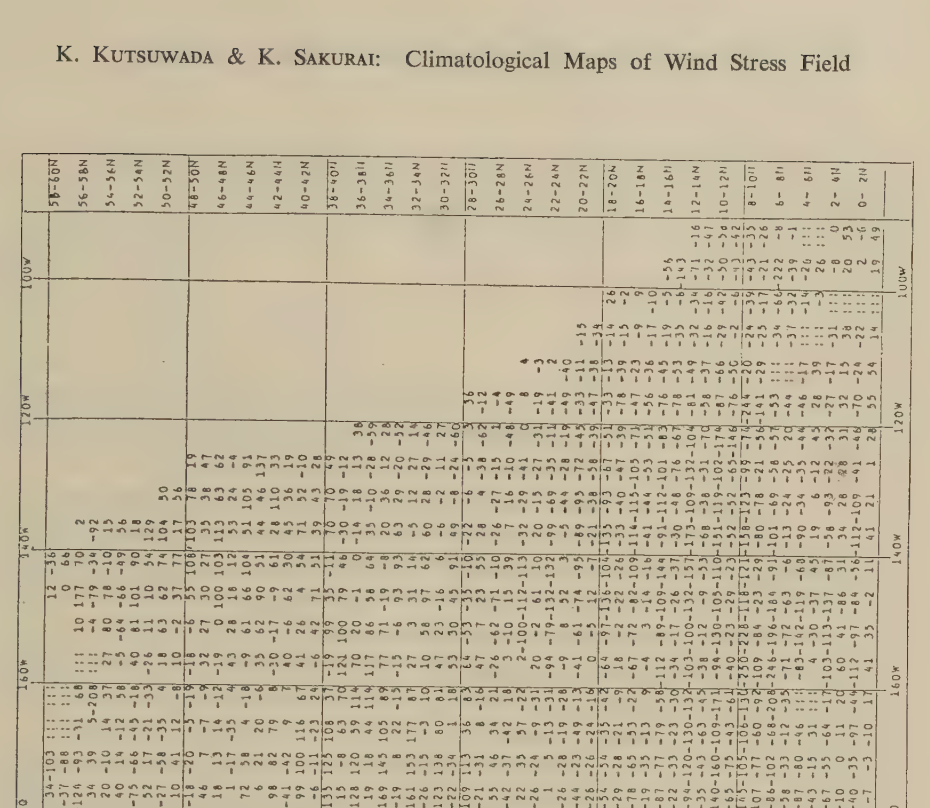

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
JANUARY

Table 2-3.

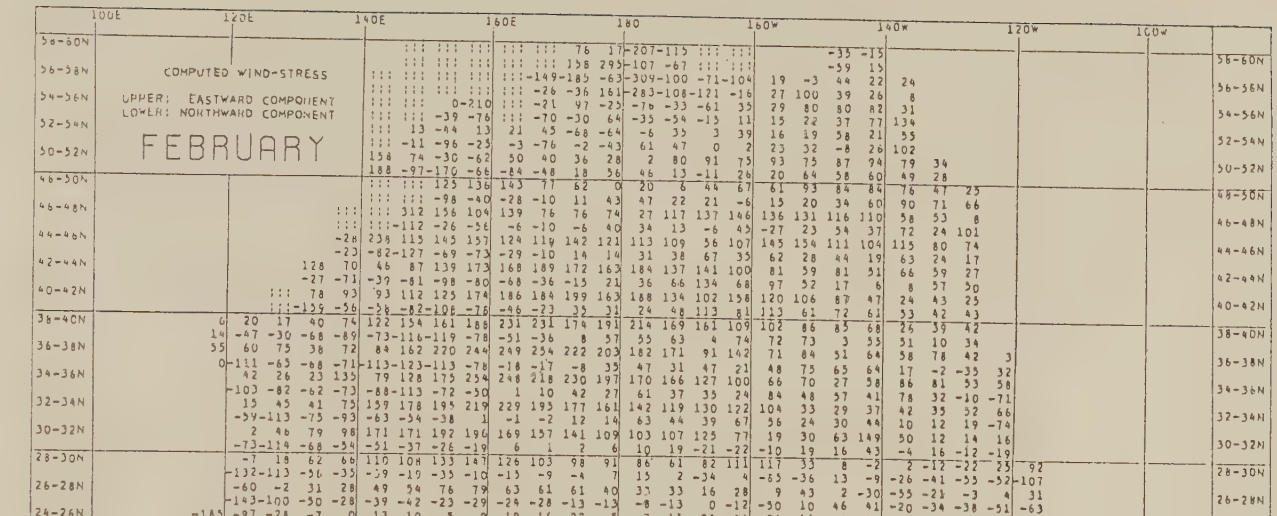

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
FEBRUARY
100E
120E
140E
160E
180
160W
140W
120W
100W
56-60N
56-56N
54-56N
52-54N
50-52N
48-50N
46-48N
44-46N
42-44N
40-42N
38-40N
36-38N
34-36N
32-34N
30-32N
28-30N
26-28N
24-26N
22-24N
20-22N
18-20N
16-18N
14-16N
12-14N
10-12N
8-10N
6- 8N
4- 6N
2- 4N
0- 2N

Table 2-4.

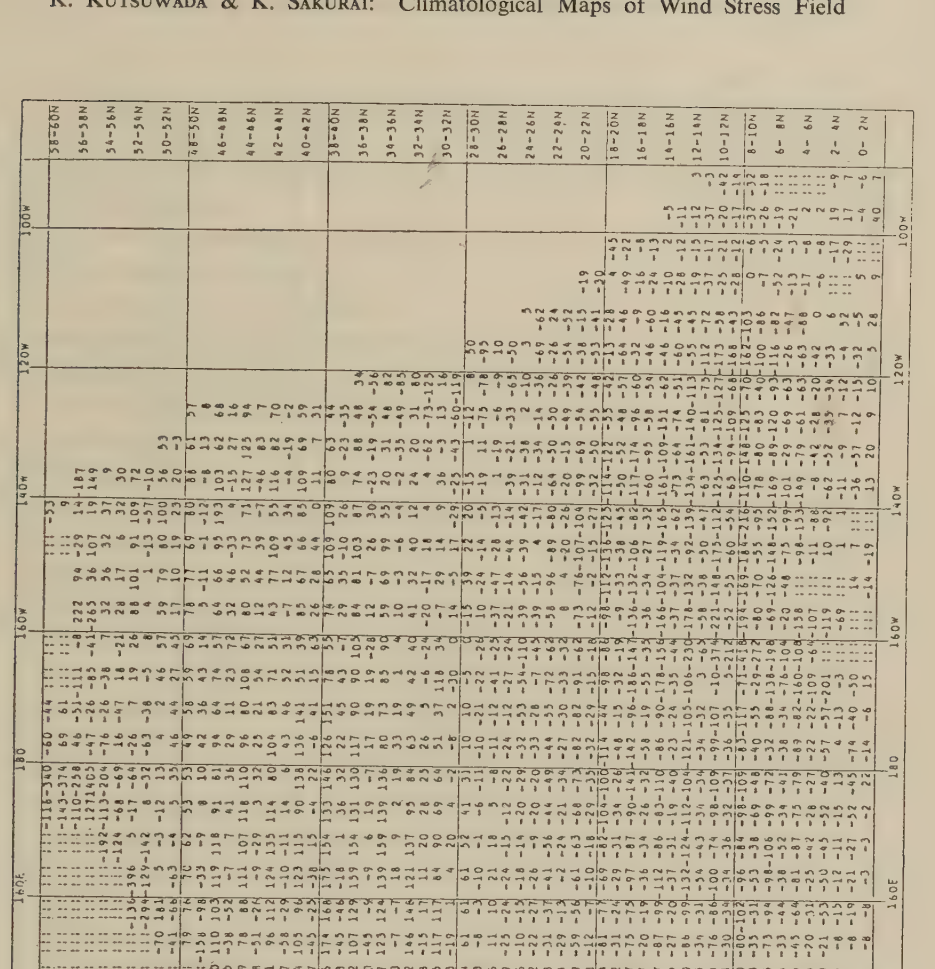

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
MARCH

Table 2-5.

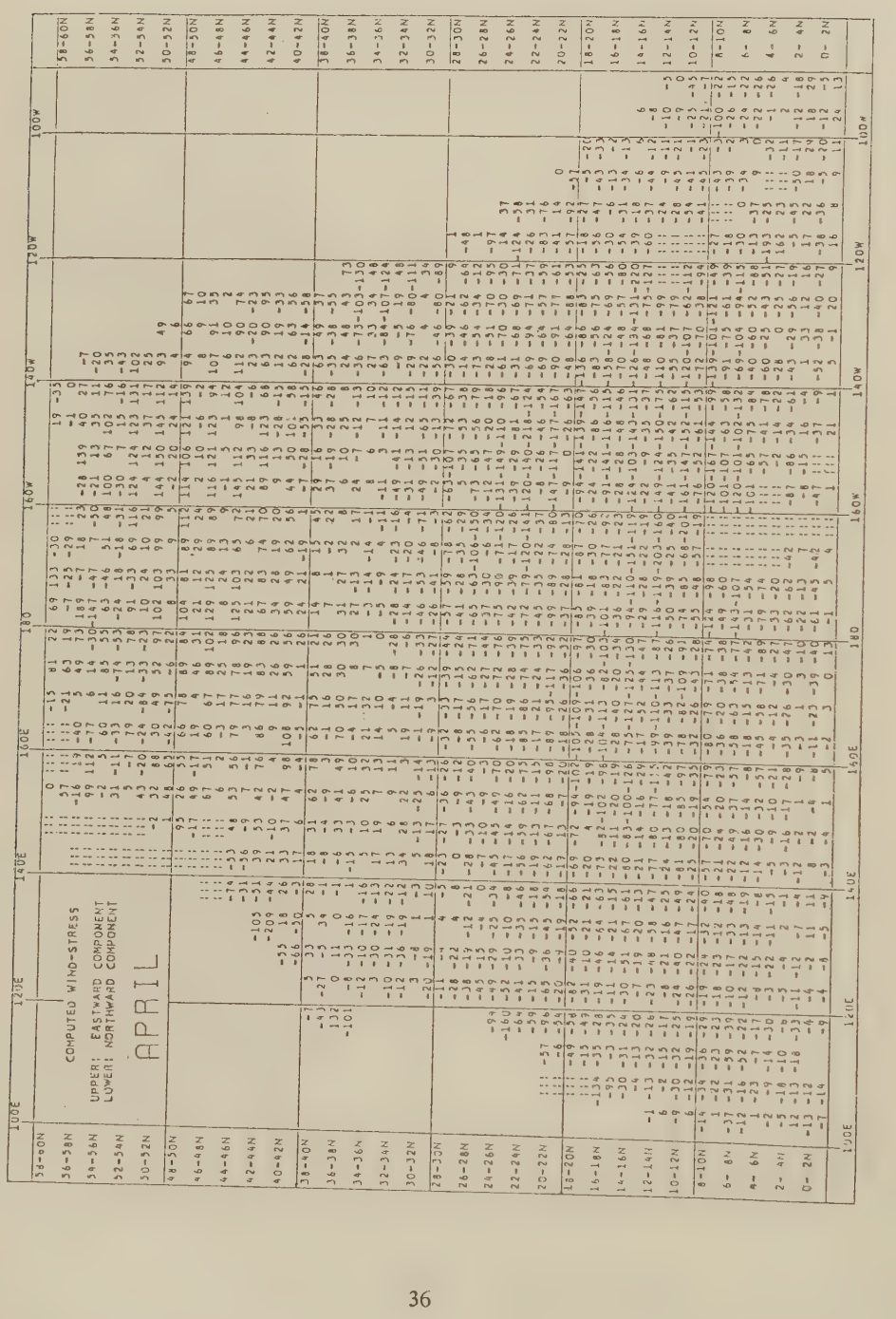

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
APRIL

Table 2-6.

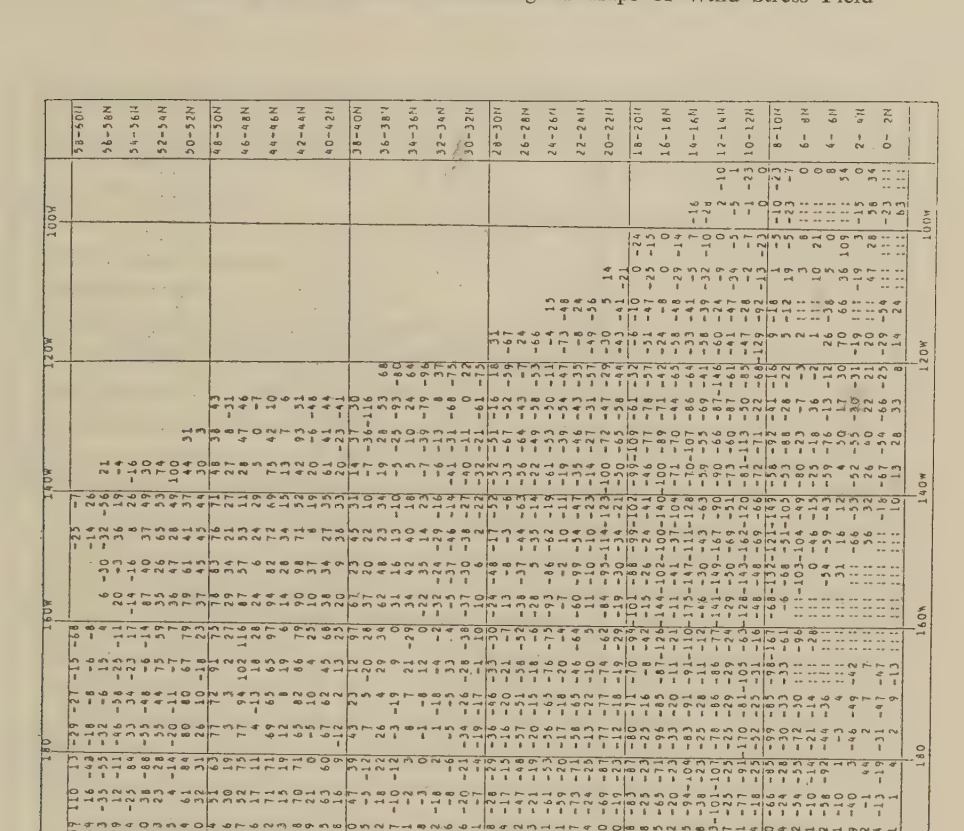

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
MAY

Table 2-7.

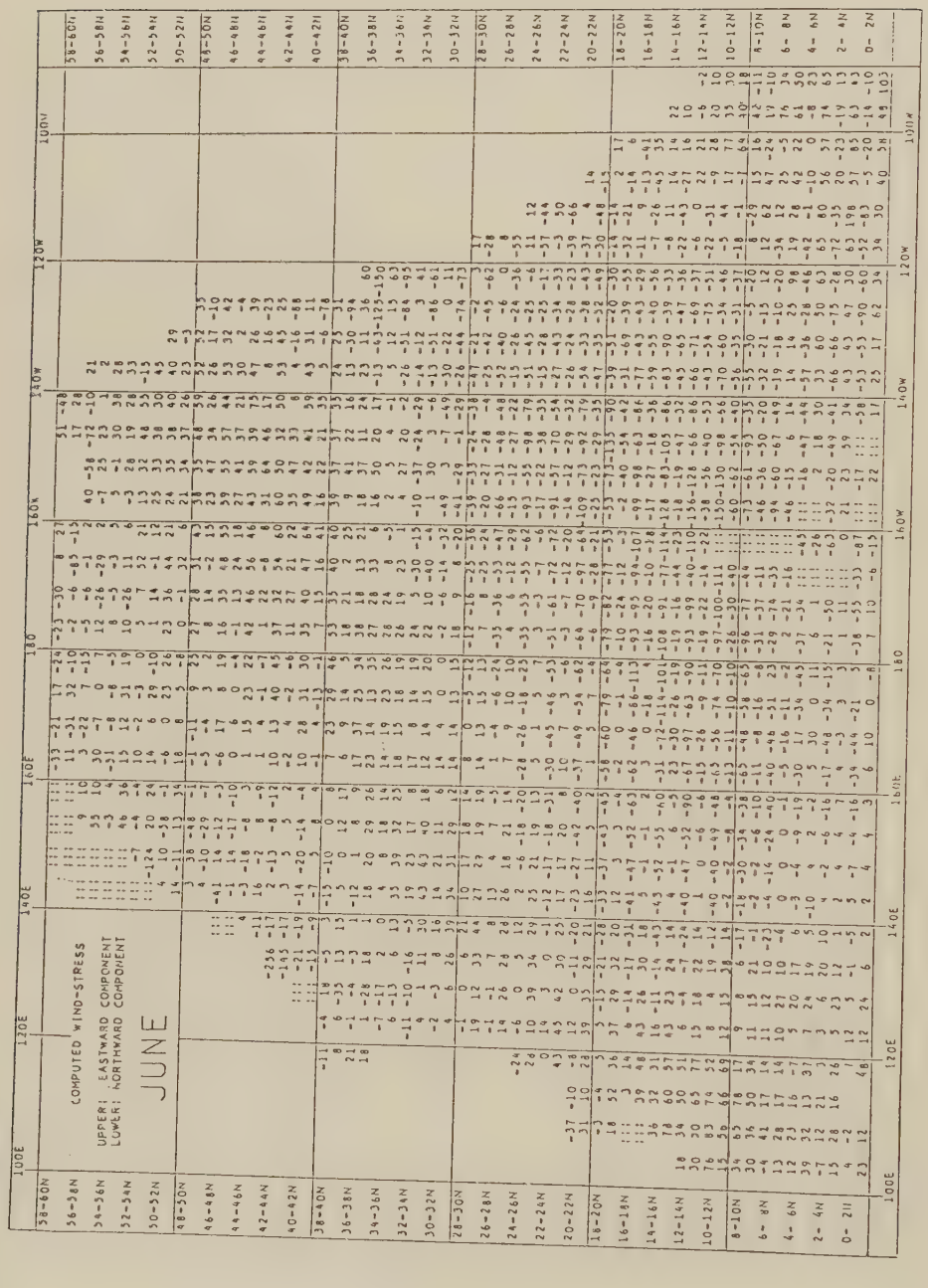

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
JUNE

Table 2-8.

COMPUTED WIND-STRESS

UPPER: EASTWARD COMPONENT

LOWER: NORTHWARD COMPONENT

JULY

	100E	120E	140E	160E	180	160W	140W	120W	100W	
58-60N			194 ::: 47	12 -36 -5 -5	-7 8 14 31	44 -16				58-60N
			231 ::: 105	12 -17 13 16	19 30 48 -13	7 3				
56-58N			58 ::: 13 11	-1 -4 -12 4	-14 43 10 15	24 -13 -45 -18	-18			56-58N
			34 ::: 17 16	65 10 21 19	9 61 32 24	33 3 3 14	19			
54-56N			-11 10 13 4	22 -19 -11 3	5 16 -14 -19	6 -5 22 35	39			54-56N
			19 48 28 41	35 -34 4 23	38 27 59 6	-8 6 19 29	35			
52-54N			-9 -7 -1 8	8 -4 4 -1	26 38 26 27	48 46 30 45	20			52-54N
			5 -18 7 16	22 -5 18 25	43 36 48 32	22 17 15 17	4			
50-52N			14 3 -7 11	10 -2 -9 16	28 37 38 41	48 40 41 37	34 32			50-52N
			30 -14 11 8	17 13 12 39	40 36 31 28	21 17 15 14	4 -2			
48-50N			-1 1 -6 19	11 12 4 11	21 26 31 34	54 51 52 42	35 27 36			48-50N
			10 15 14 8	12 16 27 34	46 36 31 33	25 14 12 21	3 -5 -39			
46-48N		38	-15 3 -3 8	21 15 15 34	28 28 33 34	48 46 46 38	29 34 34			46-48N
		103	18 3 7 4	8 18 33 36	45 38 40 32	18 14 19 13	3 -23 -29			
44-46N		-2	5 -4 -6 7	14 19 18 18	26 26 33 34	41 47 37 41	22 32 26			44-46N
		9	31 14 11 6	9 19 32 43	58 41 24 13	12 -1 7 2	-9 -60 -76			
42-44N		4 -10	-20 -5 -5 -4	4 14 15 18	16 18 19 27	38 39 34 26	18 24 22			42-44N
		2 7	8 14 10 10	16 25 36 45	48 37 24 25	21 11 7 -10	-27 -19 -29			
40-42N		::: -52 -7	-37 -6 -3 0	8 16 21 23	22 22 10 25	23 28 36 43	23 15 14			40-42N
		::: -18 9	6 11 10 10	17 30 44 49	46 29 12 30	11 -2 -4 -10	-15 -43-110			
38-40N	-14	-16 -14 -4 13	-13 0 6 9	24 27 15 11	13 3 20 21	-8 6 19 15	20 11 17			38-40N
	20	20 4 12 19	19 20 16 22	27 35 41 45	42 32 14 23	5 -11 -12 -25	-26 -54-114			
36-38N	68	-7 0 14 6	-3 6 16 16	14 15 7 4	-1 -5 -4 -6	-5 -10 -6 6	-3 -2 31 49			36-38N
	81	-6 44 30 13	29 29 25 22	26 28 41 42	36 26 -1 -22	13 -9 -12 -14	-36 -55-118 -84			
34-36N		3 -12 2 2	22 19 17 22	19 5 -8 -11	-19 -18 -13 -9	-25 -32 -30 -18	-23 -3 23 59			34-36N
		25 13 17 25	54 44 33 31	37 36 35 30	20 22 4 -20	-17 -11 -16 -26	-37 -38 -79-123			
32-34N		0 -3 1 17	25 12 17 6	17 10 -6 -29	-33 -30 -41 -31	-13 -37 -43 -46	-33 -33 -10 34			32-34N
		32 35 27 49	49 37 26 26	41 43 32 26	15 19 34 -6	-34 -22 10 -4	-35 -62 -88 -89			
30-32N		-20 -4 4 9	-4 5 4 0	-3 -18 -25 -38	-44 -43 -57 -46	-40 -32 -13 -56	-56 -43 -23 12			30-32N
		8 41 31 47	38 34 25 26	30 29 23 14	11 9 -13 -13	-34 -30 7 -15	-34 -64 -85 -74			
28-30N		11 -7 -10 -22	-25 -16 -14 -2	-13 -37 -43 -45	-58 -64 -68 -43	-56 -52 -41 -66	-57 -47 -42 -11	9		28-30N
		41 39 35 40	26 15 15 26	26 24 23 12	5 0 -3 -7	-44 -26 -14 -39	-51 -52 -70 -75	-53		
26-28N		-2 -17 -16 -24	-35 -24 -29 -45	-35 -34 -50 -54	-69 -78 -83 -73	-61 -61 -97-101	-72 -61 -43 -20	6		26-28N
		45 47 40 27	21 16 19 20	13 20 12 5	3 -1 -14 -10	-19 -31 -48 -49	-43 -54 -67 -48	-42		
24-26N	13	-9 -20 -21 -41	-36 -35 -37 -41	-38 -40 -47 -54	-57 -78 -63-116	-111-106-103 -86	-92 -59 -43 -40	-19 9		24-26N
	-30	34 47 28 27	20 20 24 13	21 16 11 6	-1 -6 -12 -20	-11 -21 -38 -43	-50 -53 -47 -57	-48 -29		
22-24N	-26	8 -17 -34 -35	-37 -33 -26 -46	-60 -59 -49 -68	-74 -73 -65-108	-104 -91 -89 -79	-65-105 -47 -37	-11 -8		22-24N
	23	44 55 27 38	26 30 18 18	23 15 6 1	-3 -9 -8 -19	-21 -20 -34 -43	-25 -62 -49 -33	-39 -19		
20-22N	33 31 -8	16 -8 -18 -18	-29 -33 -34 -44	-42 -44 -67 -62	-75 -85 -74 -63	-110 -91 -79 -95	-73 -56 -69 -38	-25 -16 -21		20-22N
	32 48 28	39 40 23 35	24 27 16 13	20 16 -1 2	-5 -9 -15 -13	-21 -22 -42 -46	-40 -48 -44 -27	-18 -21 3		
18-20N	24 15 19	31 17 3 -11	-25 -33 -30 -42	-48 -67 -64 -63	-76 -70 -76 -61	-65-115-164-110	-75 -26 -82 -36	-22 -20 -18 -28		18-20N
	15 78 51	65 38 36 44	22 22 16 15	32 21 1 -7	-8 3 -22 -11	-15 -27 -54 -63	-44 -9 -56 -30	-26 -3 26 20		
16-18N	66 34 28	22 21 11 -7	-23 -34 -43 -53	-59 -66 -68 -80	-92-104 -89 -99	-127 -96-138-110	-74 -57 -27 -37	3 -35 -15 -15		16-18N
	79 56 60	63 36 44 53	30 17 13 18	18 13 1 0	-23 -10 -4 -18	-36 -25 -37 -58	-36 -58 -32 -39	-40 -26 0 1		
14-16N	17 57 50	23 25 25 11	-16 -30 -42 -66	-62 -68 -66 -78	-85 -90 -82-142	-106 -98-134 -91	-120 -60 -52 1	19 -27 -57 -22	-6	14-16N
	40 71 74	52 41 42 29	22 13 11 10	6 -3 -10 -7	-2 -13 -27 -39	-39 -43 -51 -57	-81 -66 -98 -34	-23 -34 -31 -6	-6	
12-14N	79 23 80 85	29 38 31 19	-14 -19 -22 -37	-80-100 -82 -73	-94-103 -81-150	-102-130-127-109	-63 -20 -13 -15	-5 4 56 33	-18 -20	12-14N
	32 37 81 88	31 39 40 30	9 11 8 1	-8 -9 -11 -4	-22 -29 -41 -62	-62 -74 -81 -69	-38 -13 -55 -55	-26 -12 -13 52	-14 8	
10-12N	73 84 108 40	21 29 27 23	-6 -12 -11 -31	-45 -59 -74 -81	-100 -73 -14 -92	-90 -96-100 -29	-29 9 18 16	3 -15 -13 1	-9 -13	10-12N
	3 45 84 40	28 -35 40 23	3 5 3 -4	-5 -13 -11 -13	-39 -22 5 -29	-24 -63 -77 0	-3 45 17 24	11 12 4 20	6 2	
8-10N	53 101 111 46	19 23 32 22	13 -2 -6 4	10 -37 -52 -57	-61 -55 ::: :::	-57 -65 -75 -39	-20 -27 10 -7	4 -5 7 45	-35 -13	8-10N
	23 47 61 56	24 34 33 9	9 5 4 4	-4 -5 -23 -10	-18 -7 ::: :::	-50 -25 -55 -32	20 54 89 69	34 58 23 36	29 6	
6- 8N	18 53 41 42	9 34 29 18	15 6 2 -4	1 -24 -21 5	-39 -33 ::: :::	0 -22 -45 -19	-37 -25 -33 -63	-2 -20 1 25	::: 58	6- 8N
	16 36 15 29	22 36 25 7	7 5 5 3	1 -6 -4 9	-9 -9 ::: :::	42 24 -2 10	40 123 58 142	69 50 107 72	::: 31	
4- 6N	15 24 9 3	6 22 23 8	10 5 4 -3	-11 -6 -16 -26	-28 -29 ::: -60	-67 -88 -46 -76	-46 -58 -50 -39	-40 -49 -54 9	-4 :::	4- 6N
	43 39 7 6	12 35 22 11	7 3 5 3	0 -4 0 5	11 2 ::: 25	12 70 33 53	46 56 52 78	96 85 106 85	28 :::	
2- 4N	1 5 10 -1	-1 14 22 0	-7 -2 -2 -9	-12 -10 -26 -20	-34 -39 -94 -14	::: ::: 31 -82	-57 -67 -48 -79	0 -60 -50 -59	-3 5	2- 4N
	26 41 11 3	13 35 26 8	9 8 2 4	4 4 2 15	18 13 29 5	::: ::: 0 54	52 49 60 76	63 99 141 147	64 68	
0- 2N	4 -6 6	3 7 7 -4	-7 -6 -8 -6	-4 -18 -20 -38	-36 -26 -38 -40	::: -26 ::: :::	-87 -67 -76 -57	-70-143 -66 -27	-13 -30	0- 2N
	36 55 1	26 45 11 6	10 11 8 1	16 6 -6 15	5 12 9 14	::: -5 ::: :::	-77 16 -22 58	58 101 79 29	73 83	
	100E	120E	140E	160E	180	160W	140W	120W	100W	

Table 2-9.

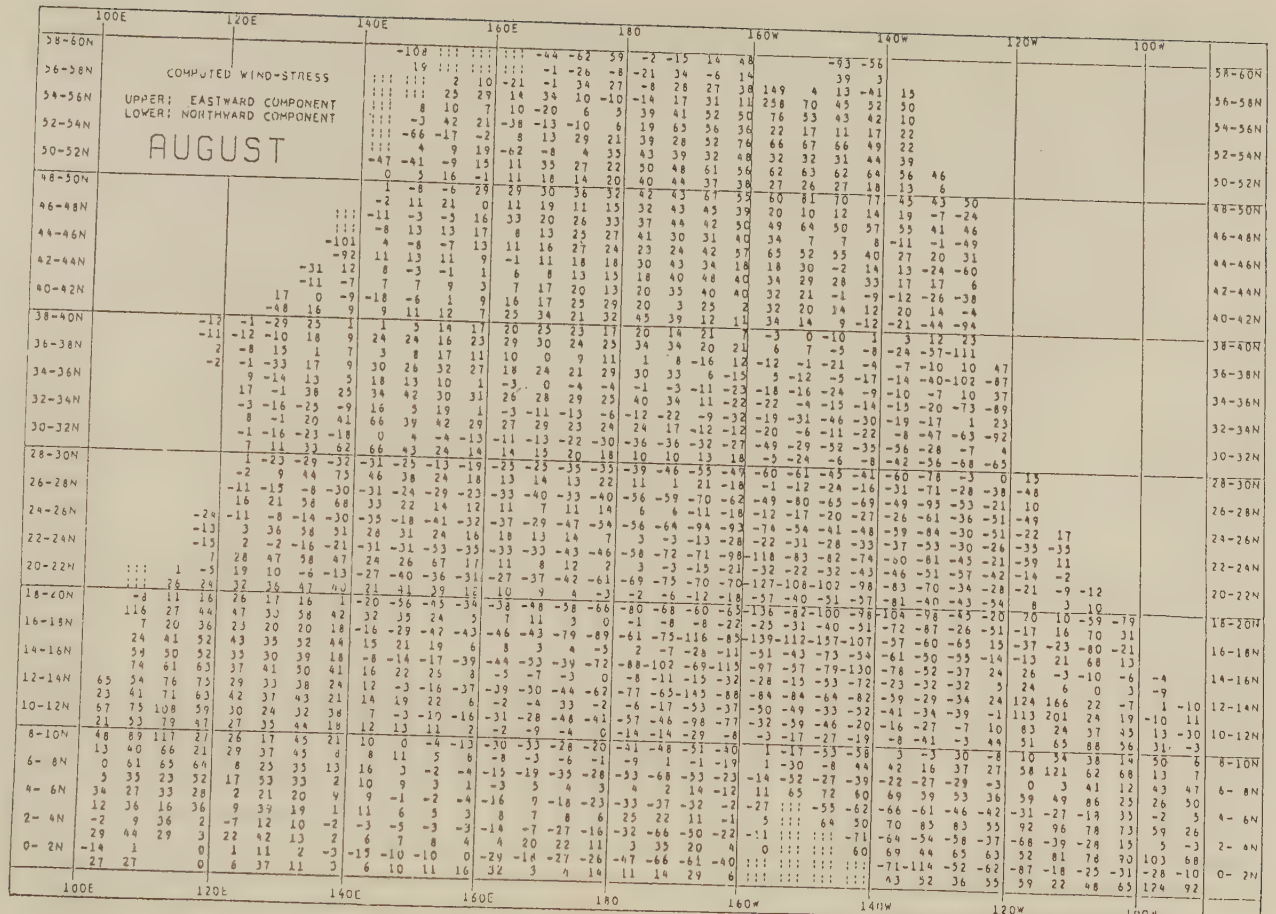

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
AUGUST
100E
120E
140E
160E
180
160W
140W
120W
100W
58-60N
56-58N
54-56N
52-54N
50-52N
48-50N
46-48N
44-46N
42-44N
40-42N
38-40N
36-38N
34-36N
32-34N
30-32N
28-30N
26-28N
24-26N
22-24N
20-22N
18-20N
16-18N
14-16N
12-14N
10-12N
8-10N
6- 8N
4- 6N
2- 4N
0- 2N

Table 2-10.

COMPUTED WIND-STRESS

UPPER: EASTWARD COMPONENT

LOWER: NORTHWARD COMPONENT

SEPTEMBER

	100E	120E	140E	160E	180	160W	140W	120W	100W	
58-60N			36	5 -22 0 -42	-9 5 56 59	-126 -22				58-60N
			42	6 72 23 -79	-9 -58 -26 121	54 20				
56-58N		0 130	-10 -15 -18 53	143 -13 35 6	-101 18 2 6					56-58N
		-683 194	-27 10 -58 -40	41 -33 11 -31	90 37 135 131					
54-56N		-8 -11	41 -46 -29 54	30 119 23 38	30 70 50 13 39					54-56N
		23 -23	-20 -38 -25 -33	-13 -30 10 23	33 16 33 46 2					
52-54N		104 0	33 40 48 28	69 110 52 58	59 75 38 37 55					52-54N
		-36 19	-17 -40 3 13	35 -35 -8 27	54 54 40 13 56					
50-52N		2 83	56 41 41 56	64 84 74 70	90 82 83 72 65 77					50-52N
		8 -11 27	30 7 -5 -9	0 -10 -8 15	26 40 27 30 48 9					
48-50N		41 55	41 38 48 71	82 72 109 111	76 75 60 71 67 75 41					48-50N
		63 19	12 22 6 5	12 -2 -6 8	30 64 50 47 28 -13 8					
46-48N		33 35	43 49 44 62	97 95 117 110	74 99 104 100 79 53 37					46-48N
		22 6	5 3 0 -9	-5 -24 6 9	22 13 42 43 33 -4 -43					
44-46N		8 28	41 53 61 54	53 87 107 113	106 81 71 69 55 38 53					44-46N
		-5 7	10 3 -3 2	-14 -10 9 -4	26 35 53 37 27 -7 5					
42-44N	24 93	0 20	30 35 46 54	61 68 100 120	71 74 55 56 26 4 -38					42-44N
	-7 -3	7 -5 3 6	7 -7 0 -5	-2 -20 12 22	40 56 40 -3 -8 -30 -111					
40-42N	30 34	-8 -7 -4	17 21 37 34	58 56 36 80	35 50 35 25 35 11 11					40-42N
	-75 -40	1 1 7	-16 -13 2 -10	-9 -10 -8 20	1 26 48 26 -23 -38 -66					
38-40N	-10 22 -31 -1 8	-17 -21 -15 -19	-5 -1 16 32	33 40 20 38	49 40 3 16 1 -12 -17					38-40N
	-31 -48 3 -10 -17	-9 0 -1 7	0 -1 -1 7	-9 -6 -49 29	46 42 2 25 -24 -74 -136					
36-38N	9 3 -20 -5	-21 -24 -21 -1	0 7 9 13	0 13 12 39	9 19 15 -12 -8 -14 26 78					36-38N
	-21 -17 -24 2	-7 7 24 14	-1 2 3 1	-17 -13 -15 -36	17 49 40 -30 -35 -54 -113 -136					
34-36N	-2 -39 -29 -25	-23 -22 -16 -29	-16 -10 -12 -11	-1 7 -21 -7	-18 -5 -6 -16 -18 -4 9 54					34-36N
	-33 -49 -33 -18	-2 12 14 14	9 6 0 3	-7 -6 -25 -11	-38 17 5 -9 -13 -36 -64 -122					
32-34N	-9 -39 -34 -30	-9 -19 -18 -29	-17 -35 -29 -18	-12 -6 5 0	-12 -22 -1 -31 -44 -13 3 32					32-34N
	-36 -60 -30 -17	13 24 8 3	3 1 -10 6	-16 -12 15 15	13 12 -9 -20 -59 -35 -52 -73					
30-32N	-12 -25 -26 -28	-13 -23 -41 -21	-31 -25 -28 -23	-21 -11 -35 -23	-23 -30 -59 -30 -26 -31 -6 12					30-32N
	-43 -42 -3 17	-22 8 17 12	-1 5 -1 2	1 -1 -25 -6	6 8 -5 -9 -27 -52 -53 -63					
28-30N	-30 -32 -33 -35	-27 -26 -25 -14	-38 -36 -38 -26	-23 -32 -36 -25	-40 -39 -25 -38 -26 -24 -5 15 21					28-30N
	-34 -38 1 36	24 6 14 14	13 1 2 -3	1 -5 -4 -25	-7 -5 -13 -25 -13 -35 -50 -52 -55					
26-28N	-38 -38 -31 -35	-33 -22 -35 -38	-29 -47 -35 -45	-38 -30 -18 -43	-81 -81 -57 -57 -45 -30 -24 8 16					26-28N
	-57 -31 2 47	16 14 14 14	6 10 4 -4	-6 -5 17 11	11 -25 -24 -21 -21 -28 -44 -41 -51					
24-26N	-165 -36 -32 -24 -46	-51 -46 -42 -31	-49 -36 -51 -42	-43 -46 -44 -49	-53 -80 -54 -38 -30 -39 -37 -12 15 -6					24-26N
	-298 -71 -5 14 32	18 22 11 12	3 7 7 -1	-4 -5 15 -11	-7 -18 -21 -19 -15 -28 -33 -61 -73 -33					
22-24N	-79 -19 -29 -43 -45	-47 -59 -55 -50	-54 -44 -49 -45	-48 -54 -61 -63	-95 -49 -63 -43 -36 -24 -33 -29 21 -31					22-24N
	-156 -31 7 24 29	26 33 34 9	10 25 14 3	-2 -7 -10 2	-33 -14 -22 -22 -34 -27 -41 -39 -50 -20					
20-22N	-66 -47 -45 -9 -19 -28 -27	-47 -51 -45 -44	-48 -51 -58 -59	-60 -58 -62 -57	-52 -59 -52 -52 -45 -35 -30 -37 -14 21 -3					20-22N
	-17 -11 -31 -3 13 26 24	38 25 33 1	8 12 4 4	-4 -14 -13 -12	-4 -15 7 -26 -23 -33 -43 -40 -40 43 34					
18-20N	-33 -11 -23 3 4 -10 -13	-29 -37 -42 -56	-51 -57 -62 -72	-71 -56 -73 -47	-76 -78 -76 -78 -58 -47 -45 0 -20 34 23 -36					18-20N
	-6 3 -8 19 5 27 31	39 28 15 16	18 12 2 -3	-1 -7 -15 -7	-7 -17 -13 -46 -43 -32 -27 -25 -40 -33 -1 27					
16-18N	-19 -2 9 11 11 19 40	-9 -34 -27 -35	-38 -43 -46 -44	-49 -73 -76 -89	-107 -84 -85 -96 -68 -47 -23 -13 3 16 39 1					16-18N
	-22 -1 18 31 14 45 60	27 19 21 8	14 15 10 2	8 1 2 -21	-33 -31 -46 -48 -48 -42 -23 -37 -33 -19 30 -3					
14-16N	61 16 19 10 23 45 45	1 -19 -20 -11	-20 -24 -33 -51	-65 -67 -2 -92	-109 -69 -70 -78 -100 -46 -46 2 1 33 36 29 -8					14-16N
	-7 24 29 6 23 34 57	24 17 18 8	19 14 10 -3	-2 -10 -37 19	-27 -17 -38 -46 -51 -33 -35 -19 -16 8 35 6 -9					
12-14N	26 34 32 24 24 33 37	9 -6 -8 -3	-46 -30 -43 -63	-63 -45 -33 -4	-72 -64 -92 -59 -57 -48 -20 10 39 15 81 39 21 11					12-14N
	31 35 36 19 25 30 30	22 14 11 12	7 5 3 5	-13 -13 15 -96	-7 -15 -22 -25 -31 -11 -25 29 22 19 44 50 27 11					
10-12N	35 66 58 19 15 20 40 16	17 4 -2 -14	-22 -32 -37 -51	-46 -33 -35	-27 -63 -28 -20 7 -5 8 -2 94 64 43 75 40 -6					10-12N
	5 35 35 12 14 20 25 3	22 16 10 -5	-2 -3 4 -3	-10 -14 -17	-18 5 -5 4 17 10 1 13 70 27 33 78 18 -4					
8-10N	39 66 72 15 16 15 40 25	46 17 3 -5	-5 -14 -28 -24	-13 -12 -59	-28 -14 -5 -7 2 -18 -4 8 -1 64 -3 22					8-10N
	16 26 32 18 13 26 31 12	22 15 11 4	-1 -3 1 8	-15 -6 -26	40 30 39 13 38 34 37 57 16 2 -5 30 8					
6- 8N	12 44 50 -34 9 32 48 13	12 14 1 -10	-8 -17 -26 -13	9 -19 5	-25 -32 -27 -10 -14 -14 11 25 20 31 31 73 9	6- 8N				
	34 24 36 -1 8 44 35 9	7 16 11 20	3 10 -2 -7	9 -3 15	37 61 64 46 40 47 95 83 71 60 50 97 34					
4- 6N	13 28 21 18 5 31 24 24	19 7 -3 -1	-14 -11 -16 -16	-21 -35 -51 -106	-23 -9 -82 -59 -35 -40 -42 -43 17 -4 -12 11 53 11	4- 6N				
	24 30 16 36 6 40 25 6	8 10 11 3	23 21 5 5	17 16 44 89	69 51 39 48 58 62 78 67 30 71 69 105 87 179					
2- 4N	-10 13 14 5 1 16 16 11	22 -1 -9 -6	-23 -16 -33 -27	-37 -40 -187	43 -21 -78 -62 -41 -60 -31 -28 -10 -3 -53 -17 7	2- 4N				
	17 33 10 9 5 34 23 5	1 9 10 2	4 6 3 5	20 18 78	43 33 60 48 38 39 40 62 123 65 65 72 15					
0- 2N	-8 -1 -10 10 13 3 -6	-5 -15 -11 -14	-25 -15 -35 -19	-38 -37 -34	-18 -30 -86 -57 -80 -43 -48 -32 -28 -25 -9 4	0- 2N				
	21 21 22 21 39 1 5	13 13 12 8	9 3 2 4	7 15 0	13 5 41 25 32 19 53 33 81 45 61 56					
	100E	120E	140E	160E	180	160W	140W	120W	100W	

Table 2-11.

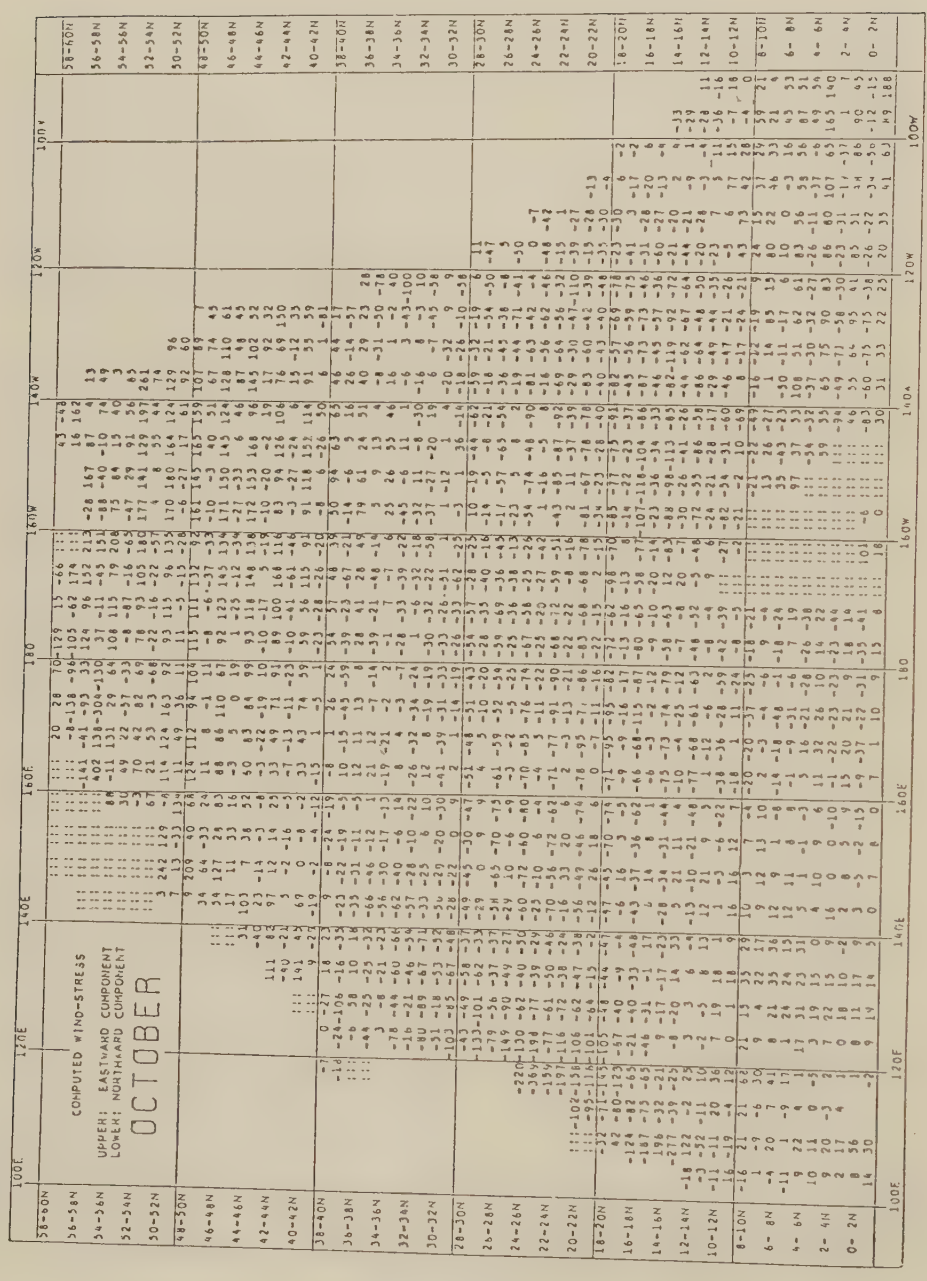

COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
OCTOBER

Table 2-12.

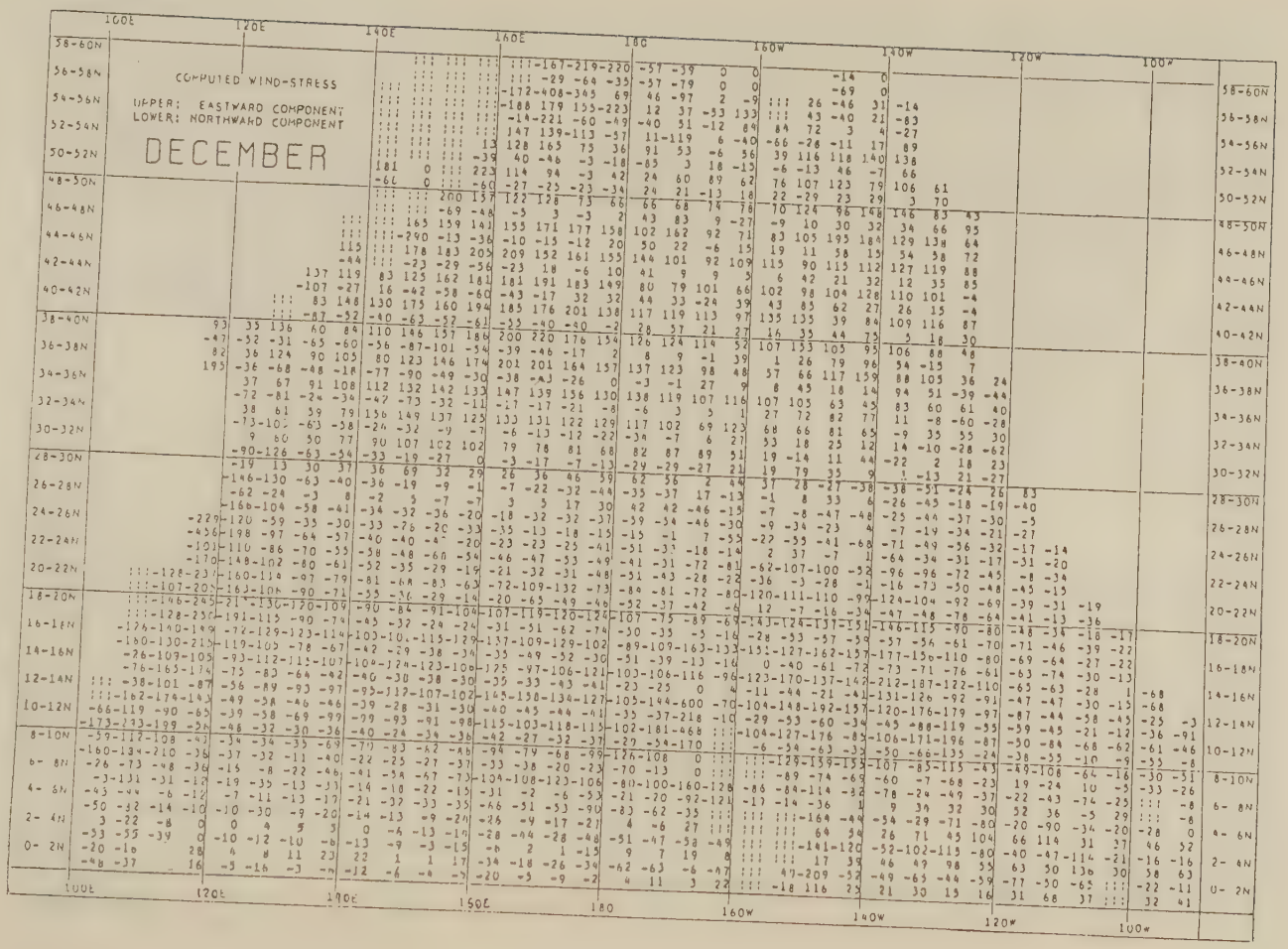
COMPUTED WIND-STRESS

UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT

NOVEMBER

	100E	120E	140E	160E	180	160W	140W	120W	100W	
58-60N			::: ::: :::	::: ::: ::: :::	-196 44 ::: :::	-260 -26				58-60N
			::: ::: :::	::: ::: ::: :::	-51-114 ::: :::	-103 -1				
56-58N	COMPUTED WIND-STRESS	76 88 ::: :::	::: 194 -48 60	138 64 13 29	::: -39 78 159	-300				56-58N
		-50 -17 ::: :::	::: -83-272-293	59-118 -4 -38	::: -27 -35 -49	150				
54-56N	UPPER: EASTWARD COMPONENT	98 131 126 :::	::: 532 -35 132	66 170 65 138	145 117 74 28	20				54-56N
	LOWER: NORTHWARD COMPONENT	-6 -41 39 :::	:::-641-221 -65	-60 -7 45 -60	-75 -4 63 37	45				
52-54N		269 ::: 258 :::	40 84 109 85	-6 168 96 129	166 163 121 110	119				52-54N
	NOVEMBER	-165 ::: 77 :::	-359-111 -11 8	-72 57 10 21	-8 7 -7 23	131				
50-52N		218 136 293 -45	165 140 136 188	131 150 130 132	136 129 173 182	109 113				50-52N
		-129 -95-134 183	-19 58 69 13	23 49 29 -1	17 34 21 30	53 23				
48-50N		::: 55 83 194	135 137 142 173	156 137 154 147	160 205 143 157	102 104 14				48-50N
		::: -55 -27 16	37 17 28 25	37 12 8 1	-29 -24 -25 -28	37 62 64				
46-48N	172	52 120 210 143	144 137 165 161	116 142 111 128	152 166 148 118	158 128 79				46-48N
	82	126 99 -38 -7	23 15 35 31	35 37 6 -21	-110 -60 -27 -69	20 24 35				
44-46N	39	162 81 122 133	162 132 185 157	146 106 131 116	126 125 189 135	140 123 57				44-46N
	-33	-12 -7 -8 -9	-14 11 0 9	21 5 51 0	31 -22 -18 -18	-12 36 54				
42-44N	28 16	124 69 112 132	129 128 106 104	93 85 95 187	132 152 192 154	151 113 78				42-44N
	-37 -11	12 0 -16 -10	5 8 -5 -8	0 24 2 -3	-5 9 39 -12	-30 34 39				
40-42N	::: 43 155	124 85 103 130	97 82 104 71	91 49 60 80	135 176 113 176	132 124 60				40-42N
	::: -67 -43	-17 -5 -8 -17	-24 -6 -26 40	10 4 11 -6	-56 7 55 -37	19 36 -7				
38-40N	19 14 121 46 66	76 94 95 98	98 72 85 75	70 43 90 58	101 112 127 100	96 91 59				38-40N
	-49 -89 9 -24 -25	-11 -28 -32 -37	-37 -26 -15 0	-36 -23 -63 1	-1 -30 -5 -3	-12 -2 -19				
36-38N	222 27 35 31 42	38 40 66 67	80 71 71 61	37 23 100 74	87 82 61 88	83 62 49 37				36-38N
	-36 -58 -22 -28 -7	-45 -37 -36 1	-15 -33 -8 1	-25 -7 -4 -15	2 16 25 -34	-44 -36 -27 -47				
34-36N	29 48 39 61	27 40 39 40	42 33 12 29	19 20 17 53	49 53 59 60	50 63 38 34				34-36N
	-30 -74 -29 -49	-21 -25 4 5	-7 -16 -21 -22	-27 -2 31 -10	-14 -12 -21 -23	-22 -46 -11 -32				
32-34N	-4 26 -1 20	3 23 25 25	22 22 16 5	-1 -8 19 8	7 1 -9 22	30 31 18 45				32-34N
	-72 -77 -55 -68	-24 -24 -38 -12	-6 -2 -12 -4	-16 -6 19 19	2 -20 3 -29	-27 -44 -26 -72				
30-32N	13 7 8 6	4 -27 -21 -16	-3 10 5 -2	-7 -17 3 -60	-43 -32 5 -6	-4 -4 -23 27				30-32N
	-81 -95 -51 -42	-23 -33 -14 -14	-15 -18 -17 -16	-7 -22 37 16	-23 -17 -12 -28	-13 -54 -67 -67				
28-30N	-27 -26 -12 -19	-25 -15 -38 -26	-32 -34 -16 -22	-30 -33 -9 -48	-45 -55 -47 -39	-52 -59 -44 -3	27			28-30N
	-107 -94 -53 -42	-24 -19 -19 -20	-17 -33 -15 -23	-24 -15 -55 -28	-5 -38 4 5	-43 -57 -37 -64	-24			
26-28N	-73 -48 -48 -40	-44 -56 -43 -40	-24 -42 -36 -48	-47 -51 -42 -68	-48 -34 -89 -76	-110 -40 -36 -20	2			26-28N
	-133-100 -70 -45	-37 -23 -9 -17	-21 -29 -33 -24	-22 -19 -13 -27	3 -18 -34 -26	-64 -21 -47 -36	-45			
24-26N	-136-138 -86 -64 -56	-55 -49 -47 -55	-70 -52 -52 -54	-58 -75 -68-135	-49 -45 -67 -72	-63 -34 -87 -36	-21 16			24-26N
	-363-206-107 -65 -46	-34 -21 -17 -18	-21 -31 -23 -18	-21 -25 -39 -62	-17 -20 -48 -40	-14 -28 -41 -39	-60 -55			
22-24N	-165-113-107 -87 -72	-71 -59 -49 -57	-67 -63 -58 -73	-85 -78 -70-116	-130-130-100 -64	-78 -79 -73 -56	-43 -17			22-24N
	-222-148-114 -77 -48	-33 -17 -13 -21	-16 -24 -17 -17	-17 -19 -6 -20	-36 -34 -28 -38	-68 -6 -49 -19	-25 -28			
20-22N	:::-213-269-167-109 -90 -77	-85 -91 -99 -78	-76 -79 -83 -80	-93 -97-114-112	-103-123-127-126	-76 -69 -58 -62	-81 -46 -50			20-22N
	:::-154-227-165-104 -67 -42	-31 -20 -3 -18	-28 -29 -35 -23	-22 -20 -23 -19	-42 -38 -40 -36	-39 -38 -52 -53	-49 -24 -22			
18-20N	-6-185-235-196 -96 -98 -77	-89 -96 -92 -98	-99 -93 -86 -86	-80-105 -82 -79	-116-111-109-156	-161-100 -65 -34	-33 -32 -13 -29			18-20N
	10-189-218-169 -87 -58 -31	-21 -14 -23 -23	-34 -28 -31 -27	-15 -28 -8 -32	-21 -36 -34 -62	-95 -59 -43 -41	-64 -33 -29 -18			
16-18N	-75-108-140 -66 -80 -90 -94	-93 -97 -97-112	-110 -80 -83-109	-56-123-142-106	-113-118-172-151	-122-102 -93 -89	-57 -25 -19 -9			16-18N
	-48-132-169-112 -67 -38 -24	-25 -17 -15 -12	-29 -29 -25 -28	-10 -11 -3 -15	-40 -60 -46 -52	-69 -99 -80-100	-57 -38 -27 -17			
14-16N	13 -90 -83 -47 -65 -72 -78	-89 -96 -89 -93	-185-118 -75 -66	-62-106-169-168	-119 -70-144-125	-143-114-102-124	-45 -56 -16 8	-31		14-16N
	-67-137-109 -38 -55 -33 -22	-21 -17 -7 -37	-74 -26 -31 -23	-16 -21 -36 -25	-19 -29 -62 -37	-58 -63 -56 -86	-64 -45 -28 -15	-24		
12-14N	-2 -23 -62 -38 -34 -42 -49 -65	-67 -81 -77 -77	-107 -91 -93 -78	-67-107-100-109	-145-116-121-139	-115-153 -92 -37	-43 -40 -34 -18	-31 -5		12-14N
	-33-138 -97 -60 -30 -43 -26 -17	-18 -8 -13 -17	-24 -25 -25 -25	-14 -24 7 -23	-18 -38 -31 -39	-60 -84 -38 -35	-29 -22 -25 -10	-15 -48		
10-12N	-6 -46 -53 -15 -30 -24 -12 -18	-30 -55 -72 -64	-69 -69 -83 -61	-54 -87 ::: -74	-81-124 -72 -86	-83 -81 -61 -50	-25 -25 -39 -30	-23 -14		10-12N
	-49-210-100 -29 -50 -25 -10 1	-10 -6 -17 -20	-30 -6 -22 -23	-23 -13 ::: 6	-36 -35 -33 -44	-45 -35 -17 -23	-4 -8 -21 -12	-28 -22		
8-10N	-21 -54 -45 3 -7 -14 -5 -30	-5 -37 -44 -54	-51 -41 -60 -69	-32 -56 ::: :::	-29-124-100 -57	-29 -73 -53 -12	-3 -23 -22-135	-17 -28		8-10N
	-116 -86-106 -4 -19 -6 -13 -10	3 -1 -13 -26	-24 -15 -21 -41	-12 -14 ::: :::	5 -38 19 20	-8 -21 -20 11	29 0 9 -24	-20 -25		
6- 8N	59 -28 -17 7 1 7 0 -16	3 -19 -29 -46	-37 -26 -47 -29	-55 -53 ::: :::	-10 -67 -52 -55	-26 -44 -30 -7	-1 2 -3 -11	-30 -6	6- 8N	
	19 -45 -13 3 -6 -17 -12 -14	6 0 -6 -2	-8 -2 -15 -37	-4 -2 ::: :::	18 -8 25 22	20 -16 2 11	28 46 16 4	-65 -23		
4- 6N	23 -15 5 -4 6 15 2 33	10 -2 -17 -23	-30 -34 -40 -33	-77 -38 ::: :::	::: -47 -39 -73	-74 -57 -20 -16	-7 -5 -6 -9	-6 15	4- 6N	
	-1 -25 1 -7 -3 -7 -5 -1	3 2 -3 -6	-8 14 -4 3	6 10 ::: :::	::: 2 35 54	53 67 48 42	54 87 37 70	73 40		
2- 4N	4 1 21 -3 12 21 11 38	23 6 2 -3	-8 0 -26 -31	-50 -66 -29 :::	::: ::: -28 -69	-64 -64 -49 -34	-21 -20 -16 -33	-12 14	2- 4N	
	-4 -12 6 6 -6 1 -7 -11	-3 -2 3 2	1 -23 9 12	7 -6 17 :::	::: ::: 48 41	48 51 39 79	55 93 73 70	100 46		
0- 2N	12 10 4 6 5 18 21	30 17 9 23	-6 -13 -22 -36	-34 -37 ::: :::	::: ::: ::: -46	-70 -77 -76 -48	-41 -40 0 -15	-13 -12	0- 2N	
	4 -2 22 2 -2 1 -3	1 -8 1 22	-3 -2 4 6	4 5 ::: :::	::: ::: ::: 18	30 32 46 23	45 50 31 26	115 49		
	100E	120E	140E	160E	180	160W	140W	120W	100W	

Table 2-13.


COMPUTED WIND-STRESS
UPPER: EASTWARD COMPONENT
LOWER: NORTHWARD COMPONENT
DECEMBER

where τ_x, τ_y are respectively eastward and northward components of the wind stress, ρ air density, C_D the drag coefficient, V wind speed and V_x are V_y are eastward and northward components of the wind, respectively.

The air density ρ was calculated from monthly mean sea level pressure and air temperature data in ten years of 1961-70 by Japan Meteorological Agency (1977). Since the spatial variation of the values depends mainly on latitudes, zonal means of monthly air densities were computed and were used in our stress computation. The values are given in Table 1.

The drag coefficient C_D were, assuming a neutral stability in the atmosphere, taken as a function of only wind speed. The relation adopted in the present work is based on GARRAT (1977) and is,

$$C_D \times 10^3 = 0.75 + 0.067V \qquad (2)$$

as shown in Fig. 1 (solid curve). Because the determination of the coefficient is still in dispute, the stress involves inevitable uncertainty caused by the drag coefficient. In the stress computation for the world ocean by HELLERMAN (1967), another relation which increases abruptly near 7 m/s^{-1} (broken curve in Fig. 1) based on DEACON et al. (1956) was used. Fig. 2 shows averages of wind speed (solid lines) and its standard deviations (broken lines). In many parts of the North Pacific, average wind speeds are between 7 and 9 m/s^{-1} and are sensitive to the relation of the drag coefficient to wind speed used by HELLERMAN. Especially in the westerly wind region between 40° and 50°N, where the standard deviations as well as averages of wind speed are large, computed stresses are more affected by the drag coefficient.

Annual mean and monthly mean wind stress fields are shown in Fig. 3 and the values of their eastward and northward components are given in Table 2. Descriptions of these results and comparisons with other stress fields (HELLERMAN, 1967; WYRTKI et al., 1976) are made by KUTSUWADA (1981).

References

DEACON, E. L., P. A. SHEPPARD and E. K. WEBB (1956): Wind profiles over the sea and the drag at the sea surface. Austral. J. Phys., **9**, 511-541.

GARRATT, J. R. (1977): Review of drag coefficients over oceans and continents. Mon. Wea. Rev., **105**, 915-929.

HELLERMAN, S. (1967): An updated estimate of the wind stress on the world ocean. Mon. Wea. Rev., **95**, 607-614.

Japan Meteorological Agency, Marine Department (1977): Marine climatological tables of the North Pacific Ocean for 1961-1970. 180 pp.

KUTSUWADA, K. (1982): New computation of wind stress over the North Pacific Ocean. Submitted to J. Oceanogr. Soc. Japan.

The Oceanographical Magazine, Vol. 32, Nos. 1-2. (1982)

WYRTKI, K. and G. MEYERS (1976): The trade wind field over the Pacific Ocean. J. Appl. Meteor., **15**, 698-704.

北太平洋における年平均海面応力場

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1961～75年の船舶資料を用いた北太平洋の海面応力が計算された。抵抗係数は風速の一次函数である。緯度 2°，経度 5° の格子領域における年平均および月平均応力が示される。

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